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Environmental Parameters in Exuma Sound and the Straits of Florida

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EXECUTIVE SUMMARY

This report is a summary and analysis of data collected during the spring of 1983 in Exuma Sound, Bahamas, and in the Gulf Stream at the Straits of Florida. Vertical profiles in the upper water column were obtained to characterize biological and chemical parameters, which might covary with propeller cavitation susceptibility.

Examination of this data set reveals that Exuma Sound is a relatively homogenous body of water with respect to the biological and chemical measurements that were made. It is an aquatic "desert," and any measurements made there of a parameter that may be influenced by biological or chemical activity cannot necessarily be extrapolated to other marine environments. This is especially true in regards to the more fertile regions, which exist in higher latitudes and coastal zones.

ACKNOWLEDGMENTS

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ENVIRONMENTAL PARAMETERS IN EXUMA SOUND AND THE STRAITS OF FLORIDA

INTRODUCTION

During 1983, the Naval Ocean Research and Development Activity (NORDA) undertook a program to characterize the environmental parameters in Exuma Sound. This effort was designed to assist the David Taylor Naval Ship Research and Development Center (DTNSRDC) in its study of the cause of propeller cavitation. The necessary samples for this study were collected on the USNS BARTLETT, Cruise 1305-83, during the period of 25 March to 5 April 1983. In addition to Exuma Sound, samples were also taken in the Straits of Florida to provide comparable results in a different body of water. The cruise track and station locations are illustrated in Figure 1.

Continuous water column measurements were made with a Neil Brown conductivity-temperature-depth probe (CTD) equipped with a transmissometer or fluorometer, and discrete water samples were collected with an attached General Oceanics Rosette sampling device mounted with 30-liter water sampling bottles. At each station, the CTD-Rosette system was lowered at least twice: once with the water samplers and a transmissometer and once with a fluorometer. Due to the configuration of the instrument package it was not possible to have both the transmissometer and the fluorometer attached at the same time. The water samplers were remotely triggered. The greatest emphasis was placed on obtaining samples at depths of prime interest to DTNSRDC: 10, 25, 75, 100, 125, 150, and 200 m. The sample statistics are given in Table 1. Table 2 contains the list of participating scientific and engineering personnel. The Appendix contains tables with the raw data.

Station 1 was used for equipment testing, and its data were not evaluated. Station 2 was as close as possible to the DTNSRDC data buoy in Exuma Sound. Stations 3 and 6 were at the same location to see what differences could be observed in the measured parameters after a 4-day period.

Stations 7 through 9 were sampled across the Gulf Stream in the Straits of Florida. There were considerable difficulties in obtaining synoptic measurements there because of the strong current drift and the operational clearance restrictions imposed on the vessel. Station 9 was further hampered by a fairly high sea state.

METHODOLOGY

A very brief description of the analytical methods follows. Most parameters were analyzed at sea. Theoretically they could have all been measured on board, but this would not have been cost effective.

Salinity: conductivity cell both continuously in situ (CTD) and on board from discrete water samples.

Temperature: Readings were made in situ with a platinum resistance electrode.

Oxygen: Micro-Winkler technique on board (Carpenter, 1965)
Nitrogen: Gas solid chromatography on board.

Fluorescence: Fluorometer in situ set at 443 nm excitation and 680 nm emission wavelengths (Lorenzen, 1966).

Chlorophyll-a: Acetone extracted material measured on board at the same wavelengths as used by the fluorometer (Strickland and Parsons, 1972).

Phaeophytin: Same as chlorophyll-a except samples were acid treated (Strickland and Parsons, 1972).

ATP: Luciferin-luciferase reaction quantified with a photometer in the laboratory (Holm-Hansen and Booth, 1966).

Dissolved organic carbon: Measured in the laboratory by wet combustion to CO_2 and infrared detection (Strickland and Parsons, 1972).

Particulate organic carbon: Material filtered on board and analyzed in the same way as the dissolved organic carbon (Strickland and Parsons, 1972).

Particles: Measured on board by electrolytic solution displacement (Sheldon and Parsons, 1967).

Light transmission: Determined in situ with a 25 cm pathlength transmissometer.

Nonvolatile organics: Measured in the laboratory by pyrolysis-mass spectrometry (Zsolnay, 1982).

Surfactants: Material from water samples that absorbed on quartz tubes on board, and then analyzed in the laboratory in the same manner as the nonvolatile organics.

RESULTS

The results from the analyzed parameters are given below. They are placed into the following categories: hydrography, gases, biological, chemical, and seston. To analyze the potential relationships between the parameters, a simple multivariate test was done. The result is illustrated in Figure 2. Each parameter was normalized by dividing it by the sum of all values for that parameter. A similarity coefficient was then determined for all the possible parameter pairs.

The similarity measurement used was the widely used and well-understood correlation coefficient (Sneath and Sokal, 1973). The absolute values for the coefficient were used, since interrelationships, regardless of direction, were of interest. This resulted in a 17 X 17 matrix of correlation coefficients. A nonlinear mapping algorithm was then applied to reduce these 17 dimensions to 2. In this way, the relative distances or similarities between all the different parameters could be more readily visualized. As one would expect, the results show that the hydrographic parameters tend to cluster together and are rather strongly interdependent. For example, the colder that water is, the more dense it will be. A more detailed discussion for each variable is given below.

HYDROGRAPHY

Background: The characteristics of the upper water layers of the western North Atlantic have been well documented and consist of 1) surface waters; 2) salinity-maximum water; 3) 18° water; and 4) western North Atlantic water (Wright and Worthington, 1970; Worthington, 1976; Emery and Dewar, 1982).

(Surface Waters): In the western North Atlantic, surface waters have a predominant low salinity equatorial component, produced in the tropics/equatorial region where precipitation exceeds evaporation. Due to the clockwise circulation this water is carried west and north, with greatest impact in the subtropical western North Atlantic. Salinity in the equatorial source region ranges from 34.9 to 36. By the time this water reaches the Bahamas area, it has been mixed with higher salinity subtropical waters to produce a typical surface salinity range of 36.2 - 36.7. Surface water temperatures are dependent on the time of year, and in the summer typically exceed 22°C.

(Salinity Maximum Water): The northeast trade winds blow across the North Atlantic between approximately 5°N and 30°N. They represent the anticyclonic circulation of the atmosphere around a permanent subtropical high pressure zone located between 30°N and 40°N (Burmuda High). In the region affected by the trades, evaporation exceeds precipitation, producing a net increase in surface water salinity. This increases the density relative to the immediate subsurface water and causes the higher salinity/higher density water to sink to a level of static equilibrium, usually between 50 and 150 m. It then spreads horizontally as an identifiable water mass and is found across most of the western subtropical North Atlantic. Near its source in the central subtropical North Atlantic, the core of the salinity-maximum water has a salinity of 37.2 - 37.3. Horizontal spreading and mixing reduces the maximum salinity with distance away from the source region until it cannot be differentiated from surface waters. In the Bahamas region the salinity core of the North Atlantic salinity-maximum water typically ranges from 36.6 to 36.9. The corresponding temperature ranges from 21.5 to 23.5°C.

The upper and lower limits of the salinity-maximum water mass are somewhat arbitrary since there is a continuous transition into the over- and underlying water types. It is convenient to define the upper limit as the base of the surface water, where the salinity gradient increases sharply, and the lower limit by the depth of the 19°C isotherm, which can be taken as the upper boundary of 18° water.

(18° Water): In the Western North Atlantic, west of 45°W and between approximately 33°N and the Gulf Stream, deep winter convection brought on by winter cooling of surface waters produces a vertically homogeneous water mass with characteristics 18 ±0.3°C, and 36.5 ±0.1 salinity. This water mass is found in a layer of varying thickness centered at about 300 m in the western subtropical North Atlantic, and has been named 18° water (Worthington, 1959).

Water Masses: Table 3 summarizes the hydrographic characteristics of each of the nine stations occupied. It is clear that the hydrography reflects the geographic relationships of the stations, which is not unexpected. This region is dominated by moderate to strong currents, which influence the measurements made at each station.

Stations 2, 3, and 6 were located in the northern half of Exuma Sound. Stations 3 and 6 occupied the same location 4 days apart. During the sampling period (28 March - 2 April) there were no significant differences in the hydrographic characteristic at these stations, as seen in Figure 3. Slight differences in the curves are not unexpected and are attributed to local effects such as internal waves.

Stations 4 and 5 were located in the southern part of Exuma Sound. They were similar to Stations 2, 3, and 6 except in the near-surface zone above 21.5°C, where the T-S relationship indicates intrusion and mixing with a lower salinity water type of unknown origin (Figure 4). The salinity anomaly was greatest at Station 5, suggesting a southern/eastern source.

Stations 7, 8, and 9 were hydrographically different from Exuma Sound (Figure 5). Station 7 exhibited the broad salinity maximum and T-S relationship, typical of the subtropical Western Atlantic. However, compared to Exuma Sound, the T-S curve was shifted to lower salinity. No evidence of dynamic mixing, as seen at Stations 8 and 9, is found at Station 7. Therefore, Station 7 must have been to the east of the Gulf Stream axis, in water transported from the south by the Antilles Current. The hydrography at Stations 8 and 9 show the dynamic affects of the Gulf Stream. At Station 8 the overall salinity was lower, but the T-S profile shows obvious interleaving of low salinity with higher salinity water. Station 8 was in or very close to the axis of the Gulf Stream. Dynamic entrainment and mixing of Antilles Current water, Loop Current water from the eastern Gulf of Mexico, and local water from the Florida shelf produces the complicated T-S relationship observed at Station 8. At Station 9 it is apparent that mixing was more complete as less interleaving structure was found. Station 9 was to the west of the Gulf Stream axis and represents, to a large degree, the influence of Florida shelf/slope water.

<u>(Density)</u>: In Exuma Sound the greatest change in density occurs at about 125 to <u>150 m (Fi</u>gure 6). This marks the boundary between the surface water and the salinity maximum water. The density of the salinity maximum water increases more sharply than does the surface water's (Figure 6). At all the stations the 18° water is below the maximum depth of chief interest to the DTNSRDC. In the Florida Straits the greatest density change at Station 7 occurs at 75 m while at Station 8 it is even shallower, being at 25 m (Figure 6). Station 9 has an increasing density with depth with no distinct pycnocline.

The stable layering of the water masses in Exuma Sound prevents the influx of nutrients into the light rich surface water, thereby strongly suppressing biological activity. It was only at Stations 8 and 9 that there was any appreciable mixing. Furthermore, it is reasonable to anticipate an accumulation of material at the pycnoclines, none was found in either the Exuma Sound or Gulf Stream waters (cf. below). This can also be attributed to the low level of biota and seston.

<u>GASES</u>

<u>(Nitrogen)</u>: Figure 2 indicates that the nitrogen concentrations are closely <u>linked with</u> the temperature. this is verified in Figure 7 where the nitrogen concentration does not begin to rise significantly until the cooler salinity maximum water. therefore the nitrogen concentrations essentially reflect the temperature of their water masses when these were at the surface and exposed to mixing with the atmosphere. On an average the cooler world ocean would have values with at least twice the magnitude of the ones reported here.

<u>(Nitrogen Saturation)</u>: Figure 8 shows no variation of nitrogen saturation with <u>depth beyond the expected</u> analytical error of ± 2%. This verifies that there were no significant sources or sinks of nitrogen in Exuma Sound or in the Straits of Florida.

(Oxygen): The oxygen concentrations below the mixed layer in Exuma Sound (Figure 9) tend to decrease monotonously with depth. The lack of sharp gradients, even at the pycnocline, indicates a sparse and homogeneous distribution of both photosynthetic and heterotrophic activity. The larger decrease at Stations 3 and 6, which were located at the same geographical location, is difficult to explain with any of the collected data.

The cause of the sharp peak in oxygen concentration at 125 m at Station 8 (Figure 9) is not readily apparent but is probably the result of the extremely complicated hydrography at that station (Figure 4). All in all, the values were quite low, about one half the oceanic average.

(Oxygen saturation): Figures 2 and 10 show that this parameter follows oxygen concentration quite closely. The saturation profiles reflect net production and consumption processes from biological activity in the water column. The upper 100 m of the Exuma Sound water is well mixed, and the resulting ventilation keeps those surface waters at equilibrium with atmospheric oxygen. Below about 100 m, the mixing is slower and the microbial activity in the water column is removing O_2 faster than it can be replaced photosynthetically or due to mixing.

BIOLOGICAL ACTIVITY

(Chlorophyll-a): This is probably the most universally used indicator of phytoplankton biomass. The values found at all stations were quite low. On an average, one would expect three times greater concentrations in the world ocean and 30 times higher values in coastal regions. Under bloom conditions the amount of chlorophyll-a can be 1,000 times greater than the amounts found here.

Exuma Sound did have the expected maxima in the photic zone (Figure 11). Station 3 differed from Station 6 by having its maximum at a shallower depth, presumably because it was sampled later in the day and 4 days earlier. Station 2 had the smallest maximum. This may be due to its being the most landlocked of all the stations.

The Straits of Florida samples are remarkably uniform (Figure 11), considering the complicated hydrography at two of the stations there. The conclusion is that all of the water sampled in the photic zone was of poor quality for phytoplankton activity, regardless of the hydrography.

(Fluorescence): This parameter has the advantage of being measurable in situ. It should be roughly related to chlorophyll-a, and therefore also be a good first order approximate of plytoplankton activity. There was some similarity between fluorescence and the chlorophyll-a concentration in this study (Figures 2 and 12). A scatter plot is shown in Figure 13. The relationship would have been better had the chlorophyll-a and fluorescence measurements been truly synoptic. They were not because the water samples were usually obtained during a different cast than that used to measure fluorescence. The reason for this was that other devices also had to be launched during the course of each station.

(Phaeophytin): This pigment is a common breakdown product of chlorophyll after it has passed through the digestive tract of the zooplankton. Therefore, it is a good indicator of grazing activity. The results illustrated in Figure 14 are very low. The chief conclusion is that there were very few active zooplankton

present. In other bodies of water the expected concentration of phaeophytin would be larger roughly to the same degree as the chlorophyll-a concentrations would be larger.

(ATP): This organic molecule is present in all living cells and is, therefore, used as a rough indicator of active microbial life. "Total" ATP (i.e., ATP in cells between 0.2 µm and 200 µm) was the parameter measured in this study, and as seen in Figure 15 it generally shows the same trends as the other biochemical parameters: chloroplyll-a and phaeophytin. Divergence of the ATP trends from the other parameters indicates the presence of concentrations of bacteria and nonphotosynthetic microflagellates. World ocean values would be about 30 times greater with 100 times greater values in coastal regions.

CHEMICAL AND SESTON

(Particulate organic carbon): The values were very low (Figure 16), often being at the limit of detection (0.01 mg/L). World ocean values would be about 5 times greater and coastal ones at least 20 times larger.

(Dissolved organic carbon): The concentration of this parameter shows no conspicuous maxima that would indicate strong biological activity (Figure 17). The qualitative "fingerprinting" of the nonvolatile organics were remarkably similar in all the samples analyzed. A representative one is shown in Figure 18. This type of analysis is still in its early stages of application. Therefore, there are no other open ocean results to which these results can be compared. They, however, will provide a valuable basis of comparison should this type of research be done in a different body of water.

(Surfactants): This group of organics is of considerable interest in this type of study because of the role that it may play in bubble stabilization. The results indicated a remarkable uniformity. Figures 19, 20 and 21 show the averaged results for shallow (10 m), mid (100 m) and deep (200 m) water samples, respectively. Since the results are so uniform and this approach so new, one is tempted to doubt them. However, the average of the blank values is quantitatively and qualitatively quite different (Figure 22). Therefore, the results cannot be dismissed, but additional studies will have to be made for purposes of comparison.

(Small particles): Small particles are considered to be seston between 1.2 to 10 µm (equivalent spherical diameter). The results are given here in counts per liter rather than in volume distributions per liter. This is based on the assumption that the possibility of particles being cavitational nuclei is more a function of their number than their size. In Exuma Sound there are small maxima at 25 m (Figure 23). This is above the zone of biological activity. Therefore it most likely is aeolian transported material. There is an additional maximum for Station 2 at 100 m. Perhaps this is also related to it being the most land-locked of the stations.

The results from the Straits of Florida are about of the same magnitude (Figure 23). There is no relation to any of the biological parameters (Figure 2). Therefore, one possible conclusion is that most of this material is allochthonous with an aeolian source.

(Large particles): Large particles are defined as having equivalent spherical diameters of 10-100 μm. The results indicate maxima in four of the stations at the near surface depths (Figure 24). There appears to be some correlation between the larger particles and the particulate organic carbon (Figures 2 and 25). This would indicate that these larger particles are some type of nonchlorophyll containing organisms or organic seston. However, the outliers in Figure 25 are from the samples that had the larger counts of the particulate material in the 10-100 μm size range. Therefore, one could conclude that the material at 10 m at the four stations in question is inorganic and presumably has an aeolian source. Artifacts from the ship are also a possibility. Caution is needed because the very low counts and low particulate carbon values result in a less than ideal scatter plot (Figure 25).

(Beam attenuation coefficient): This is a useful parameter, since theoretically it should be related to the number of particles present in the water column. It has the advantage of being relatively simple to obtain and is well suited for in situ measurements. In Exuma Sound the values are among the lowest in the marine environment (Figure 26), and are quite similar among the different stations there. However, Stations 3 and 6 both have relatively high values in the depth range of 25 to 75 m.

The Straits of Florida show more erratic results as would be expected, but they are still very low (Figure 26). There is a relationship between the small particle counts and the attenuation coefficient (Figures 2 and 27). It is not very strong, having a correlation coefficient of only 0.721, but it would presumably be considerably better if the measurements had been truly synoptic.

CONCLUSIONS

As has been frequently observed in this text, both Exuma Sound and the Straits of Florida were relatively barren as reflected in the uniformly low values of the chemical and seston parameters measured in this study. The small amount of seston present was probably allochthonous, introduced through aeolian transport. The gases were also present in low concentration because of the warmth of the water.

It was hoped to find a more fertile region on the land side of the Gulf Stream to compare with the Exuma Sound results. However, this was precluded at the time of sampling because the Gulf Stream was simply too close to shore. As a result, any conclusion obtained from these two bodies of water can only be applied to the local areas tested and not extrapolated to other regions.

For any future program with limited resources, we would recommend, besides the necessary hydrography, the analyses of fluorescence and light transmission in situ. In this way one can obtain reasonable estimates of both biological activity and particle concentrations. This should be done in a considerably more productive region. The results obtained there can then be analyzed and the need for a more detailed study, such as the one reported here, can be evaluated.

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TABLES

TABLE 1

SAMPLE STATISTICS

Stations	9
CTD-Rosette Casts	20
<u>Discrete Samples</u>	
Oxygen	108
Nitrogen	108
Particulates	108
Nonvolatile organics	108
Surfactants	20
ATP	108
Pigments	108
Salinity	108

TABLE 2

SCIENTIFIC PERSONNEL

Name	Title	Affiliation
Briggs, Stephanie	Associate Chemist	CSC*
Eckstein, Bruce	Design Engineer	NORDA
Gowing, Scott	Design Engineer	DTNSRDC
Lavoie, Dennis	Oceanographer	NORDA
Levenson, Maria	Associate Chemist	CSC
Shen, Young (Dr.)	Senior Naval Architect	DTNSRDC
Velinski, David	Associate Chemist	CSC
Wiesenburg, Denis (Dr.)	Oceanographer	NORDA
Williams, Robert	Electronics Technician	NORDA
Zsolnay, Adam (Dr.)	Oceanographer	NORDA

* Computer Sciences Corporation

TABLE 3

HYDROGRAPHIC CHARACTERISTICS OF STATIONS OCCUPIED DURING CRUISE 1305-83

Water Type	Boundary (m) (Upper)	(Center)	(Lower)	Temperature (°C)	Salinity Range
			Station 2 (Exuma Sound)		
Surface	0		120-126	23.1-23.7	36.61-36.65
Sal. Max.	120-126		277-283	19.0-23.3	36.58-36.78
18° Water		320-363		18	36.5
			Station 3 (Exuma Sound)		
Surface	0		115-120	23.3-23.8	36.64-36.68
Sal. Max.	115-120		263-275	19.0-23.4	36.61-36.79
18° Water		320-330		18	36.5
			Station 4 (Exuma Sound)		
Surface	0		140	23.5-24.1	36.62-36.67
Sal. Max.	140		265-270	19.0-23.5	36.60-36.77
18° Water		340-355		18	36.5
			Station 5 (Exuma Sound)		
Surface	0		100-110	23.6-24.4	36.61-36.65
Sal. Max	100-110		280-282	19.0-23.8	36.60-36.77
18° Water		336-350		18	36.5
			Station 6 (Exuma Sound, same position as Station 3)		
Surface	0		117	23.3-24.3	36.61-36.67
Sal. Max.	117		256-264	19.0-23.4	36.61-36.79
18° Water		340		18	36.5
			Station 7 (Gulf Stream/Antilles Current)		
Surface	0		72-81	24.9-25.1	36.08-36.16
Sal. Max.	72-81		172-176	19.0-25.0	36.14-36.74
18° Water		199-201		18	36.4+
			Station 8 (Gulf Stream)		
Surface	0		63-66	24.7-25.1	36.10-36.16
Sal. Max.	63-66		146	19.0-24.8	36.13-36.70
18° Water		159		18	36.4+

TABLE 3 (CONT'D)

HYDROGRAPHIC CHARACTERISTICS OF STATIONS OCCUPIED DURING CRUISE 1305-83

Water Type	Boundary (m) (Upper)	(Center)	(Lower)	Temperature (°C)	Salinity Range
		Station 9 (Gulf Stream/Florida Shelf Water)			
Surface	0		25	22.9-24.9	36.02-36.13
Sal. Max.	25		91	18.0-22.9	36.02-36.15
18° Water	NOT DETECTED				

FIGURES

Figure Legends:

1. Track of USNS BARTLETT Cruise 1305-83.

2. Nonlinear map of the distances between the similarity coefficients obtained from 17 different measured parameters. The axes are arbitrary, but the closer the symbols are, the greater the covariation between the parameters. Lines connect those parameters that appear to have a significant covariation. The circles are of the same arbitrary size and are only used to assist in the evaluation of relative distances between the symbols (parameters). The symobls stand for the following parameters:

   A. chlorophyll-a concentration,
   B. phaeophytin concentration,
   C. ATP concentration,
   D. small (1-10 μm diameter) particle counts per liter,
   E. large (10-100 μm diameter) particle counts per liter,
   F. dissolved organic carbon concentration,
   G. particulate organic carbon concentration,
   H. oxygen concentration,
   I. oxygen saturation,
   J. nitrogen concentration,
   K. nitrogen saturation,
   L. depth,
   M. temperature,
   N. density,
   O. change in density,
   P. fluorescence concentration, and
   Q. beam attenuation coefficient.

3. Plot of salinity vs. temperature at Stations 2, 3, and 6 in Exuma Sound.

4. Plot of salinity vs. temperature at Stations 4 and 5 in Exuma Sound.

5. Plot of salinity vs. temperature in the Straits of Florida (Gulf Stream).

6. Density as a function of depth in Exuma Sound (top).

   Density as a function of depth in the Straits of Florida (bottom).

7. Nitrogen concentration as a function of depth in Exuma Sound (top).

   Nitrogen concentration as a function of depth in the Straits of Florida (bottom).

8. Nitrogen saturation as a function of depth in Exuma Sound (top).

   Nitrogen saturation as a function of depth in the Straits of Florida (bottom).

9. Oxygen concentration as a function of depth in Exuma Sound (top).

   Oxygen concentration as a function of depth in the Straits of Florida (bottom).

10. Oxygen saturation as a function of depth in Exuma Sound (top).

    Oxygen saturation as a function of depth in the Straits of Florida (bottom).

11. Chlorophyll-a concentration as a function of depth in Exuma Sound (top).

    Chlorophyll-a concentration as a function of depth in the Straits of Florida (bottom).

12. Fluorescence concentration as a function of depth in Exuma Sound (top).

    Fluorescence concentration as a function of depth in the Straits of Florida (bottom).

13. Scatter plot showing fluorescence vs. chlorophyll-a concentrations.

14. Phaeophytin concentrations as a function of depth in Exuma Sound (top).

    Phaeophytin concentrations as a function of depth in the Straits of Florida (bottom).

15. ATP concentrations as a function of depth in Exuma Sound (top).

    ATP concentrations as a function of depth in the Straits of Florida (bottom).

16. Particulate organic carbon concentrations as a function of depth in Exuma Sound (top).

    Particulate organic carbon concentrations as a function of depth in the Straits of Florida (bottom).

17. Dissolved organic carbon concentrations as a function of depth in Exuma Sound (top).

    Dissolved organic carbon concentrations as a function of depth in the Straits of Florida (bottom).

18. Typical pyrolysis-mass spectrum obtained from the nonvolatile organics in the water samples. This sample was obtained from 75-m depth at Station 3 in Exuma Sound. The abscissa is in atomic mass per charge units. The ordinate is normalized to the fragment with a mass of 79 and is proportional to the quantity of each fragment present. Quantification is done with digital counts, and RIC in the upper-right corner refers to the total counts that were present in this sample.

19. Pyrolysis-mass spectrum surface active material from 10-m depth. This is an average of all the analyzed samples from that depth. The abscissa is atomic masses per charge. The ordinate gives the relative quantity of each fragment to the total of all the fragments present.

20. Same as Figure 30, but for the average of all the samples analyzed from a depth of 75 m.

21. Same as Figure 30, but for the average of all samples analyzed from a depth of 200 m.

22. Nonlinear map showing in two dimensions the distance between all the similarity coefficients obtained from the analyses of the surface active material. The closer the symbols are, the greater is the similarity between the samples that they represent. The symbols stand for the following samples:

    B. blank
    S. shallow water samples from Exuma Sound
    s. shallow water samples from the Straits of Florida
    M. mid-water sample from Exuma Sound m. mid-water sample from the Straits of Florida
    D. deep-water sample from Exuma Sound
    d. deep-water sample from the Straits of Florida.

23. Small (1-10 μm diameter) particle counts from Exuma Sound (top).

    Small (1-10 μm diameter) particle counts from the Straits of Florida (bottom).

24. Large (10-100 μm diameter) particle counts from Exuma Sound (top).

    Large (10-100 μm diameter) particle counts from the Straits of Florida (bottom).

25. Scatter plot of large particle counts vs. particulate organic carbon concentrations.

26. Beam attenuation coefficient from Exuma Sound (top).

    Beam attenuation coefficient from the Straits of Florida (bottom).

27. Scatter plot of the beam attenuation coefficient vs. small particle counts.

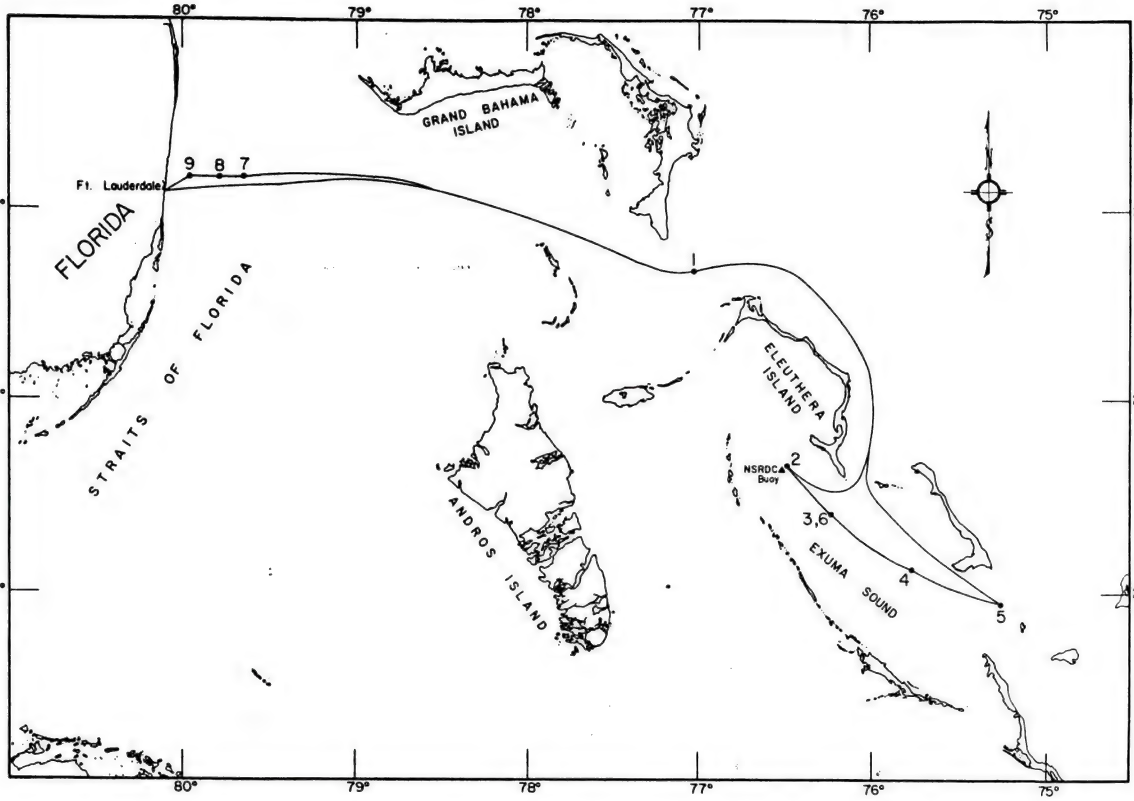


Figure 1. Track of the USNS BARTLETT Cruise 1305-83.

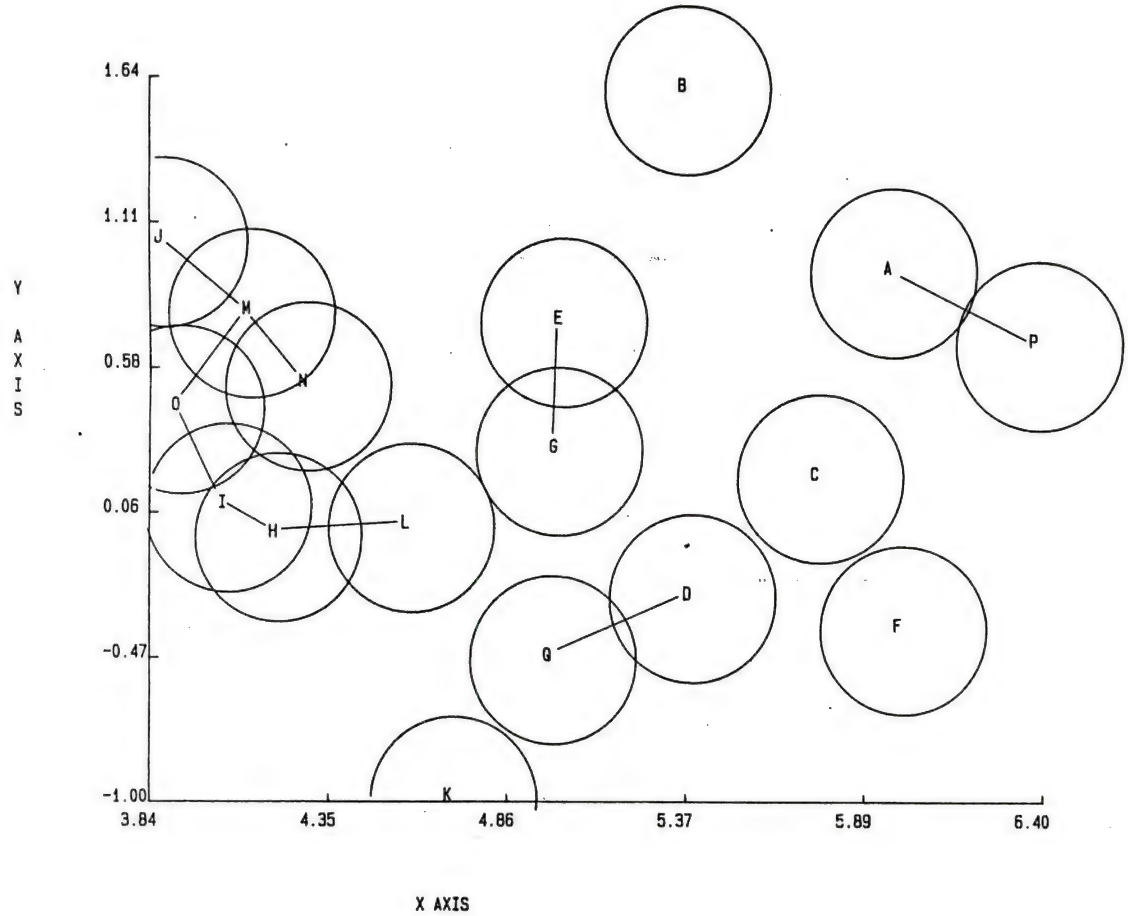


Figure 2. Nonlinear map of the distances between the similarity coefficients obtained from 17 different measured parameters. The axes are arbitrary, but the closer the symbols are, the greater the covariation between the parameters. Lines connect those parameters that appear to have a significant covariation. The circles are of the same arbitrary size and are used only to assist in the evaluation of relative distances between the symbols (parameters). The symbols stand for the following parameters:

A. Chlorophyll-a concentration
B. Phaeophytin concentration
C. ATP concentration
D. small (1-10 µm diameter) particle counts per liter
E. large (10-100 µm diameter) particle counts per liter
F. Dissolved organic carbon concentration
G. Particulate organic carbon concentration
H. Oxygen concentration
I. Oxygen saturation
J. Nitrogen concentration
K. Nitrogen saturation
L. Depth
M. Temperature
N. Density
O. Change in Density
P. Fluorescence concentration
Q. Beam attenuation coefficient

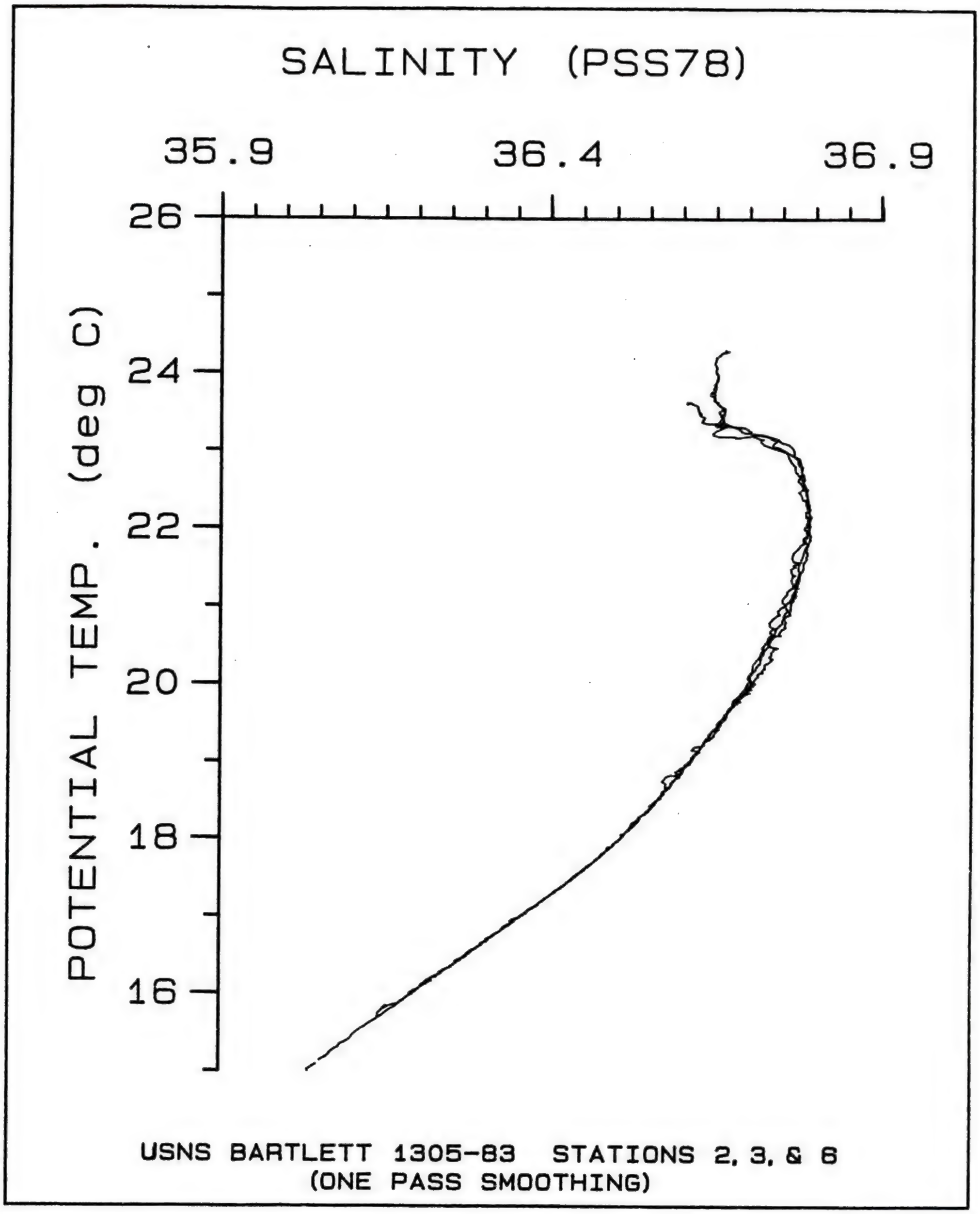


Figure 3. Plot of salinity vs. temperature at Stations 2, 3, and 6 in Exuma Sound.

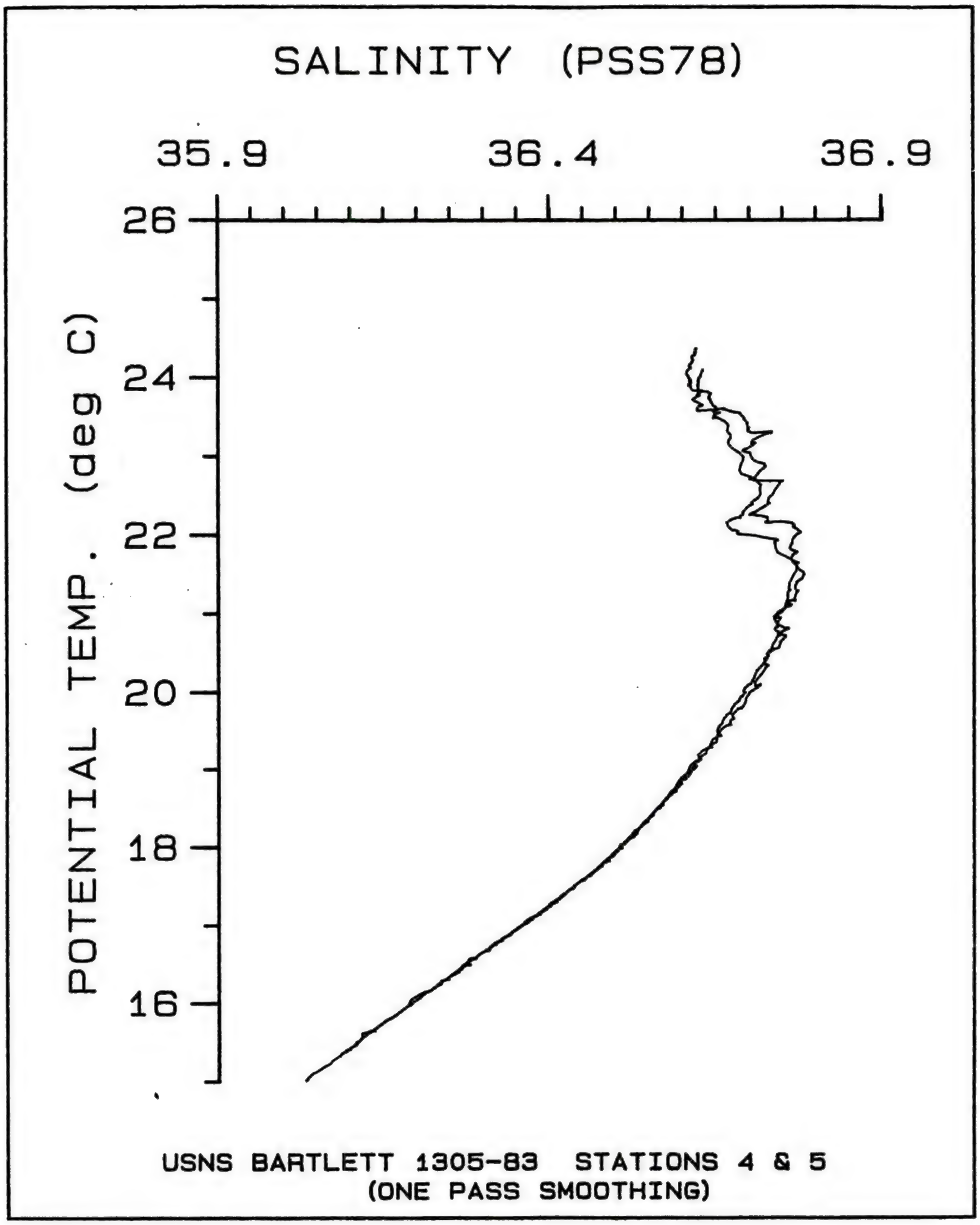


Figure 4. Plot of salinity vs. temperature at Stations 4 and 5 in Exuma Sound.

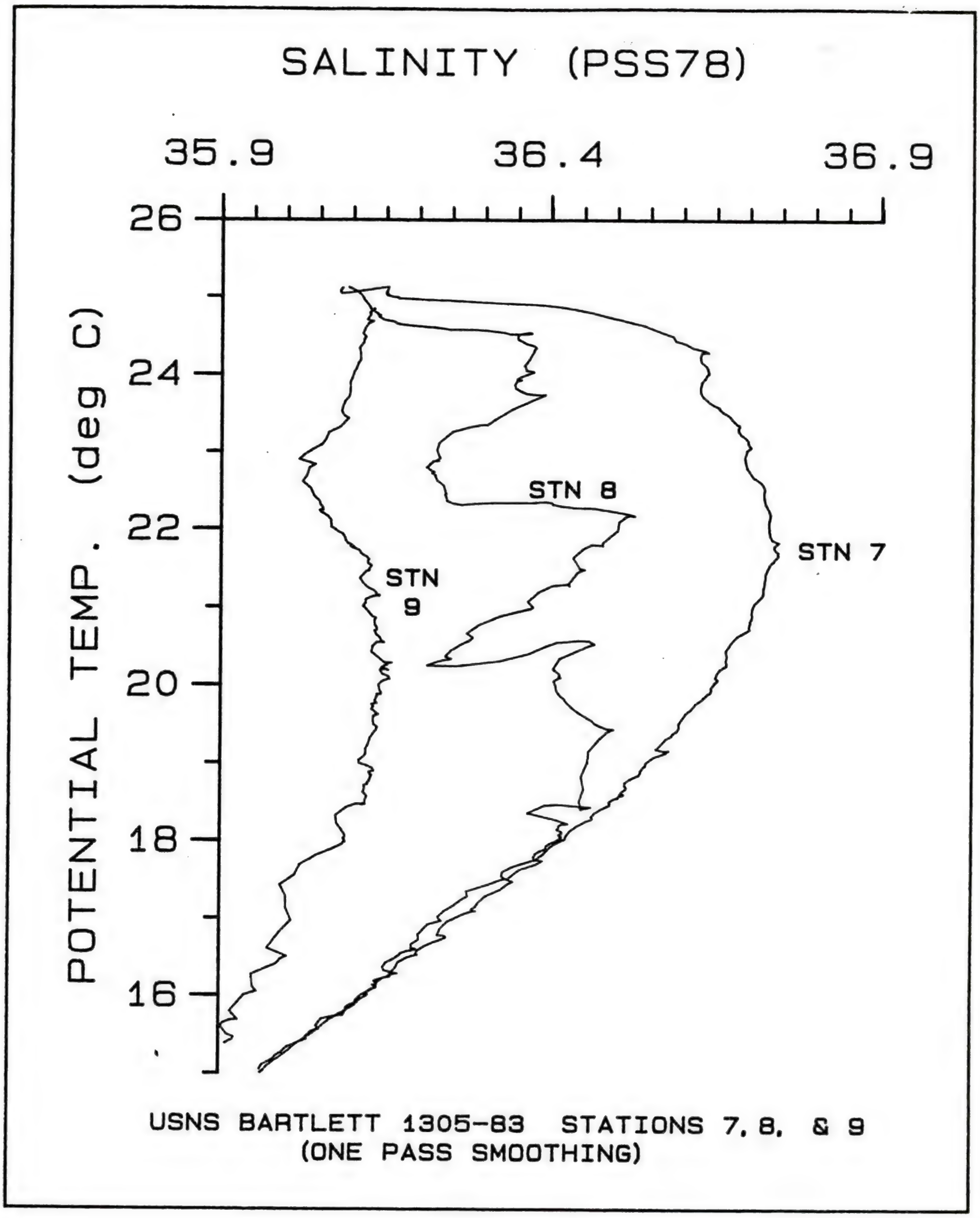
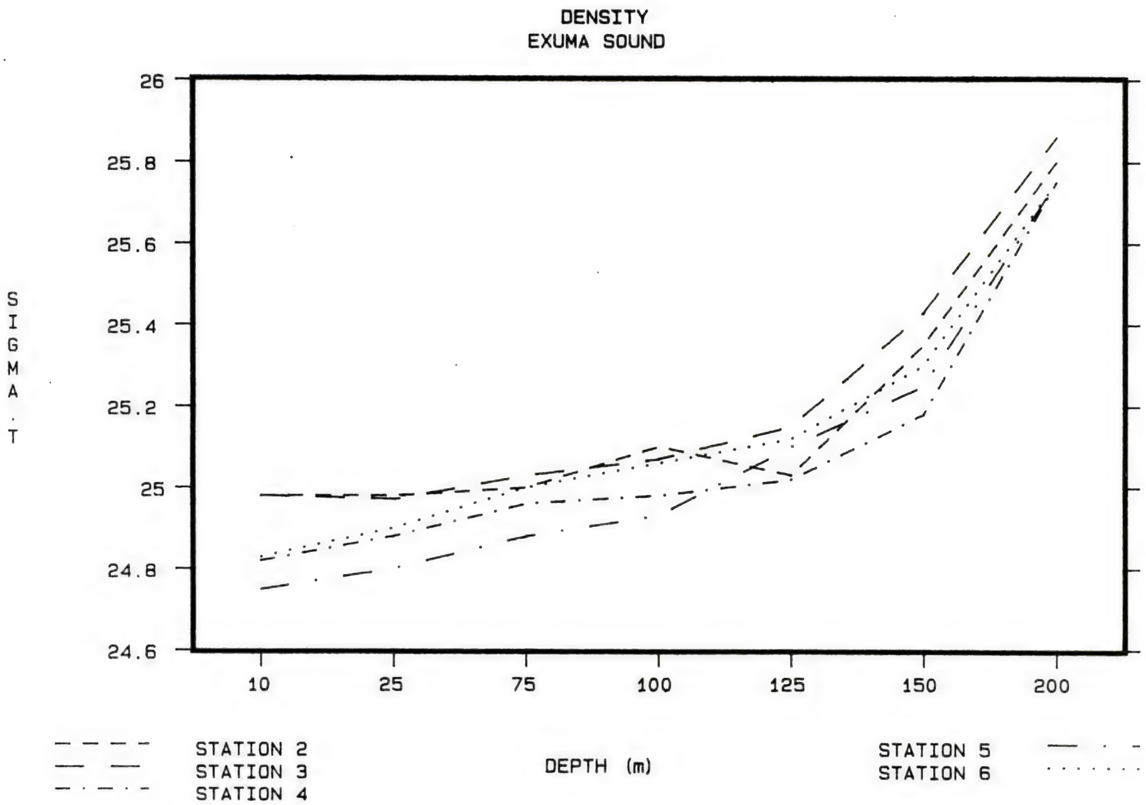


Figure 5. Plot of salinity vs. temperature in the Straits of Florida (Gulf Stream).



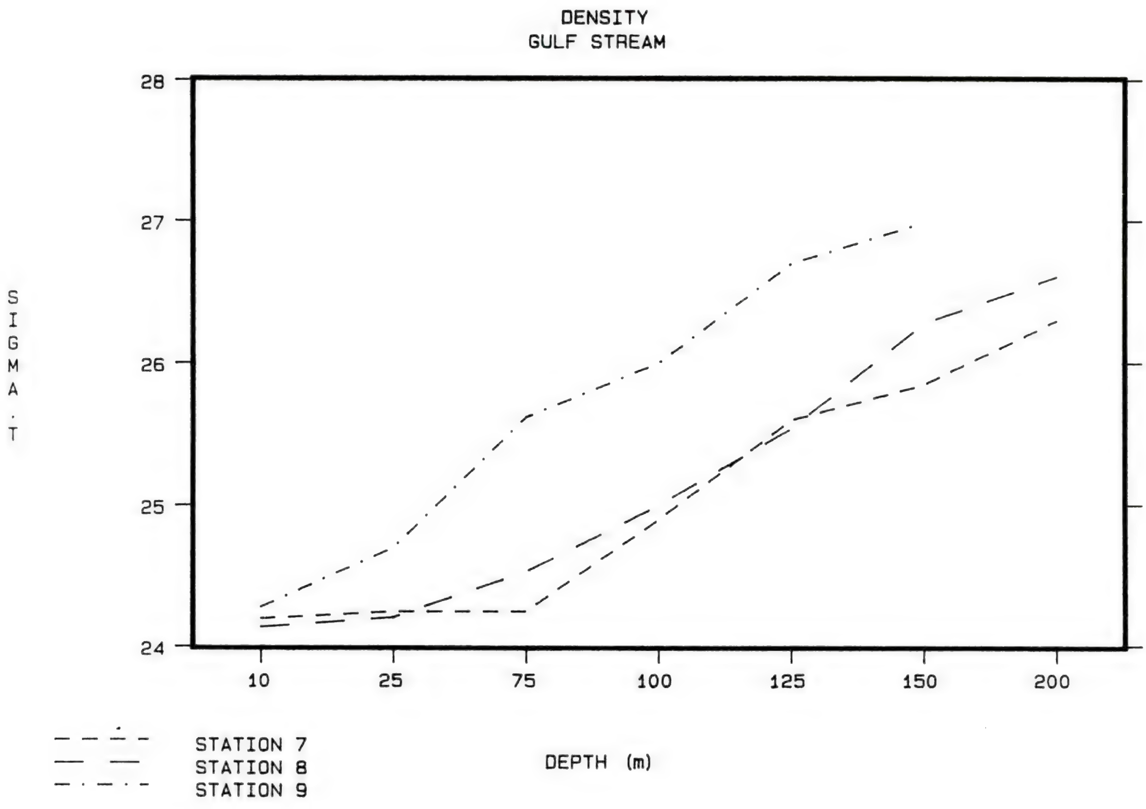
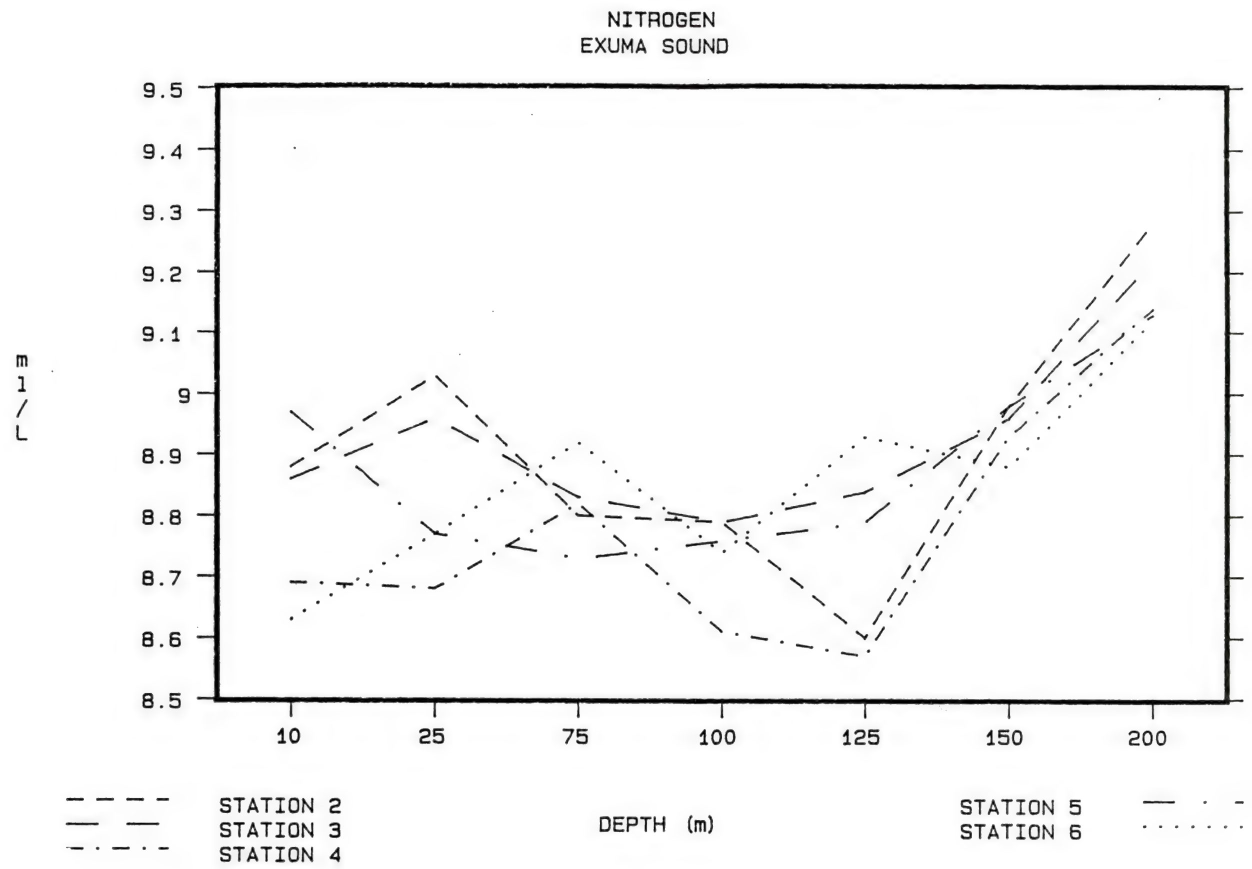


Figure 6. Density as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



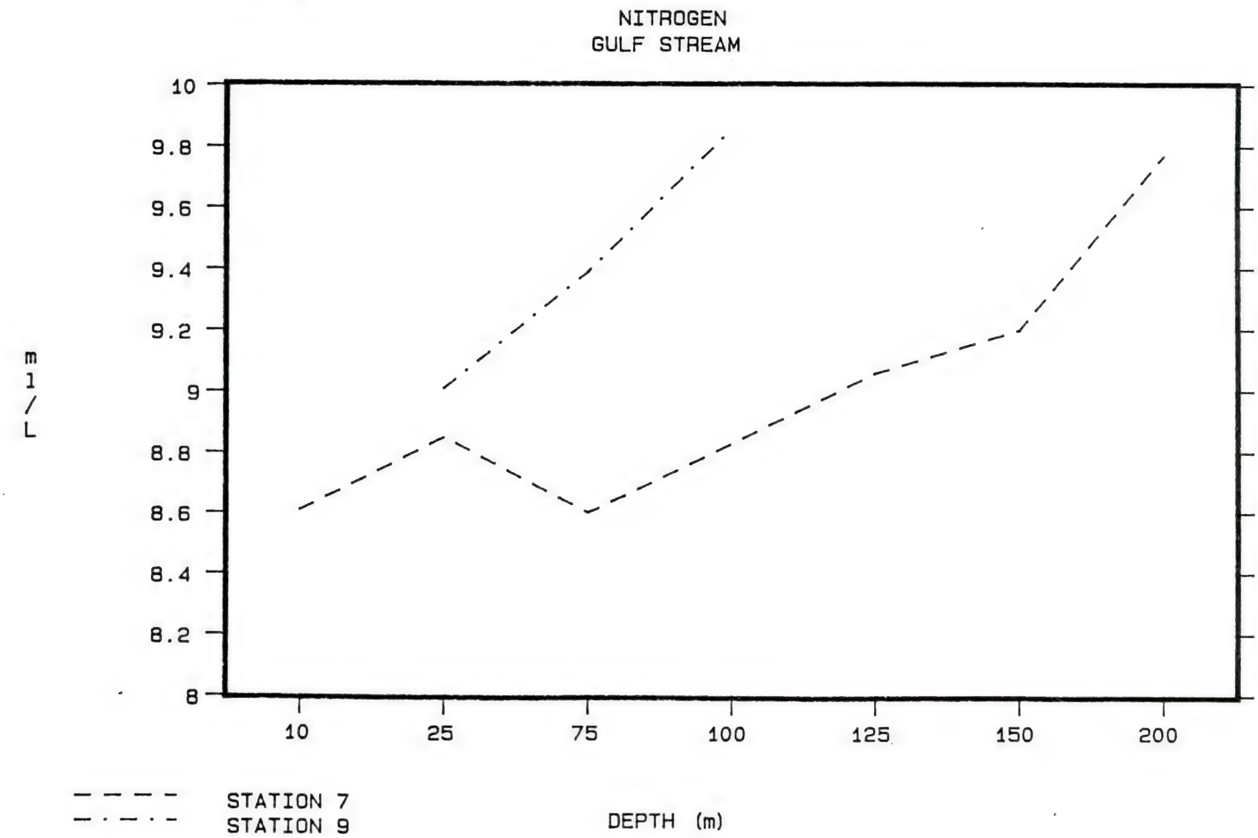
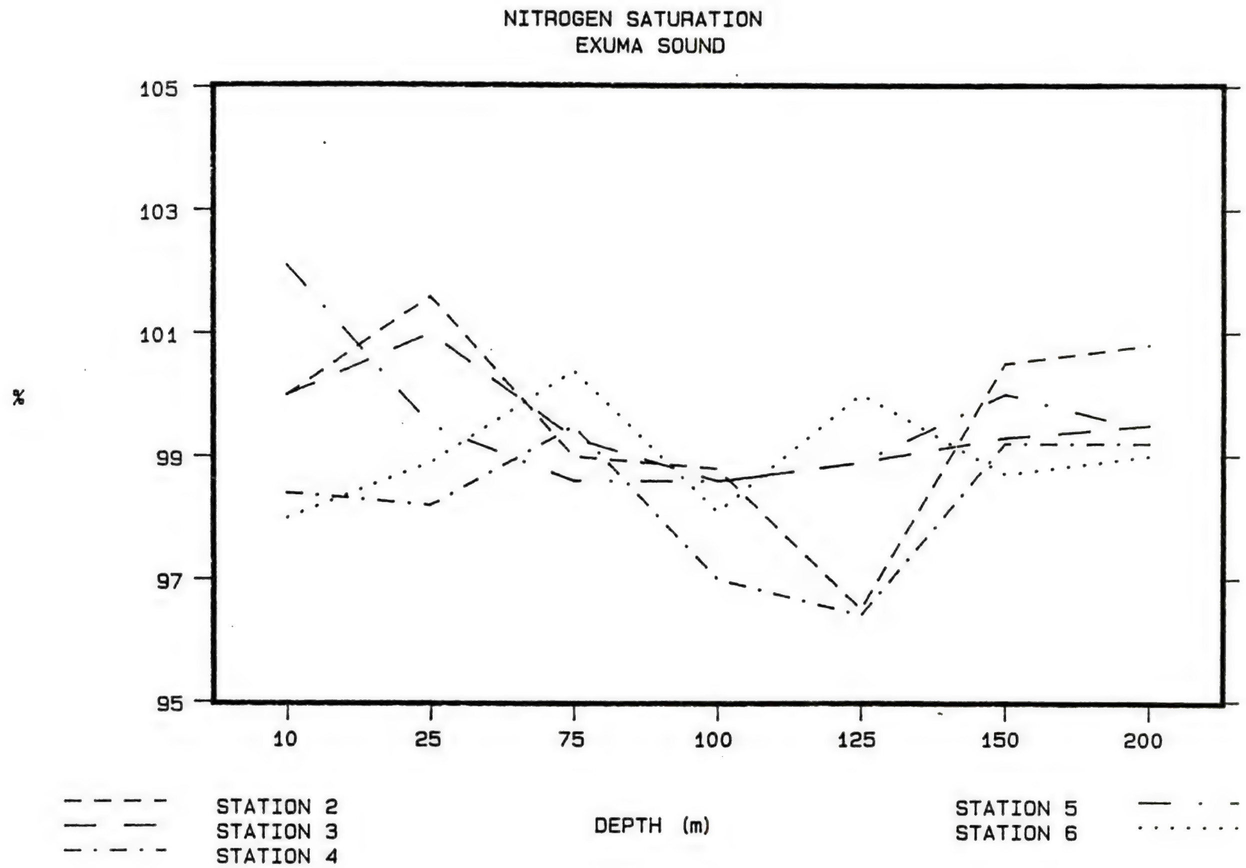


Figure 7. Nitrogen concentration as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



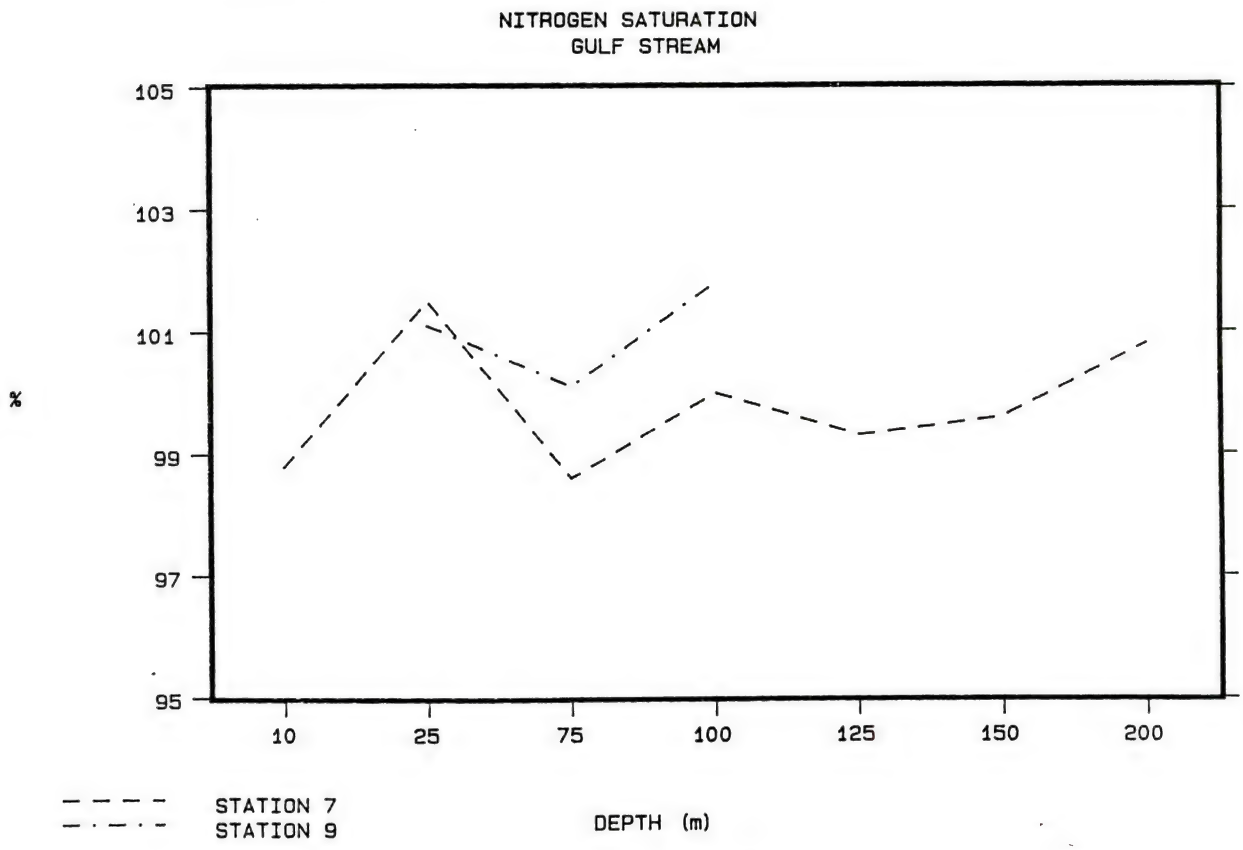
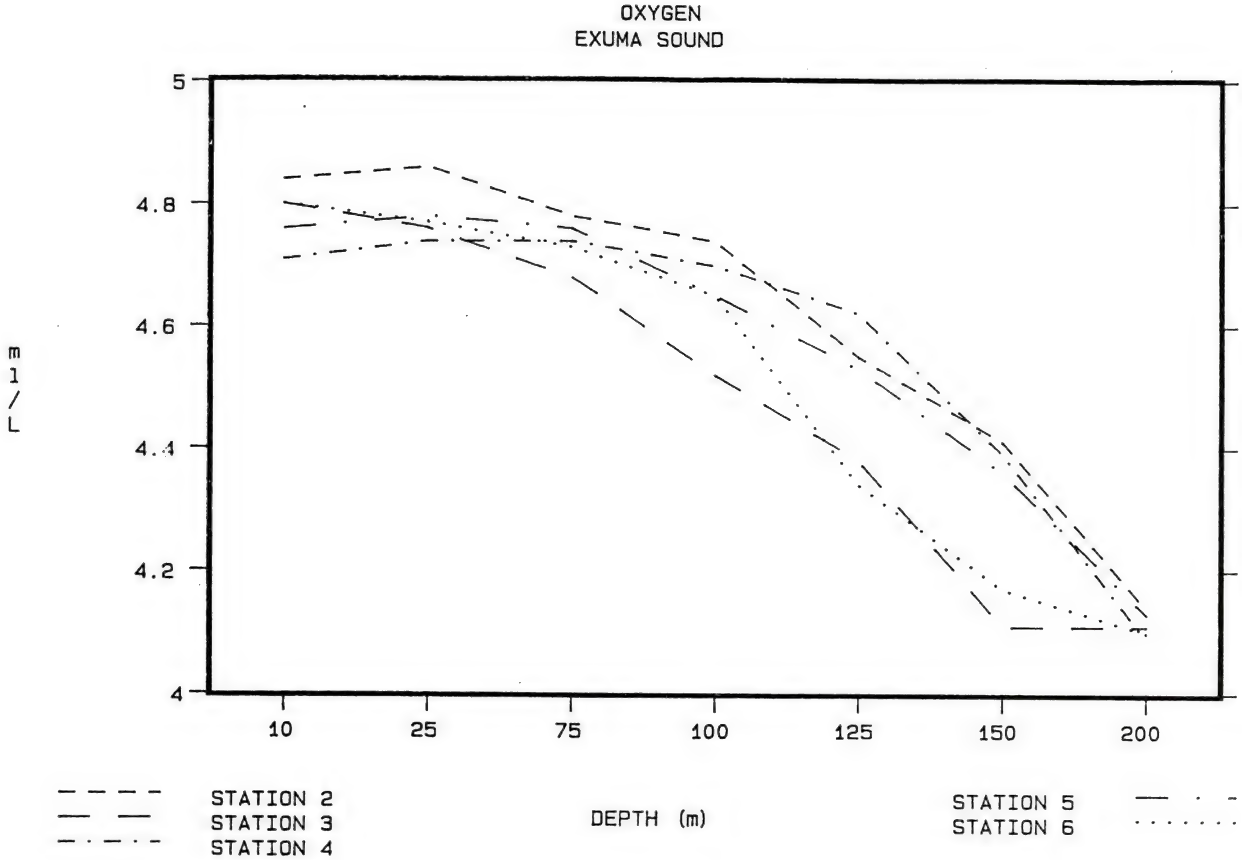


Figure 8. Nitrogen saturation as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



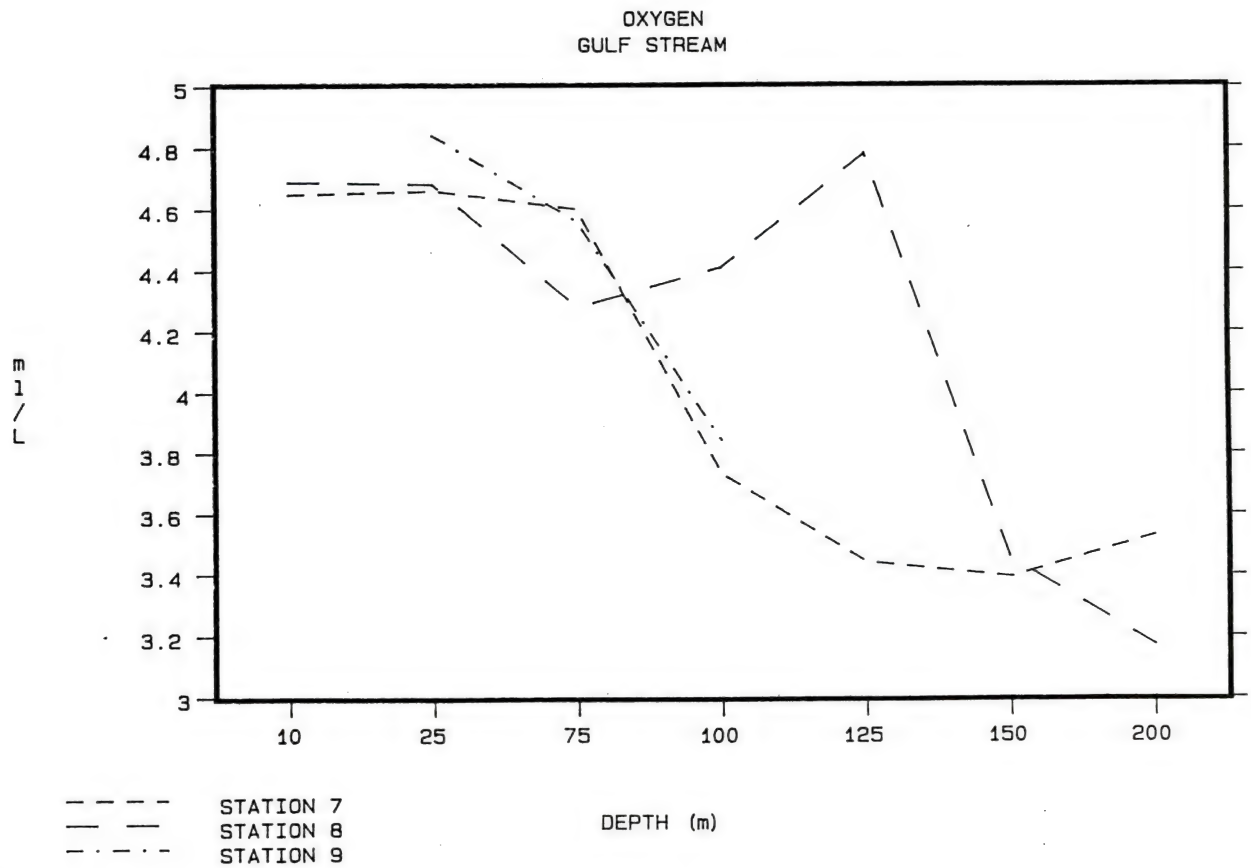
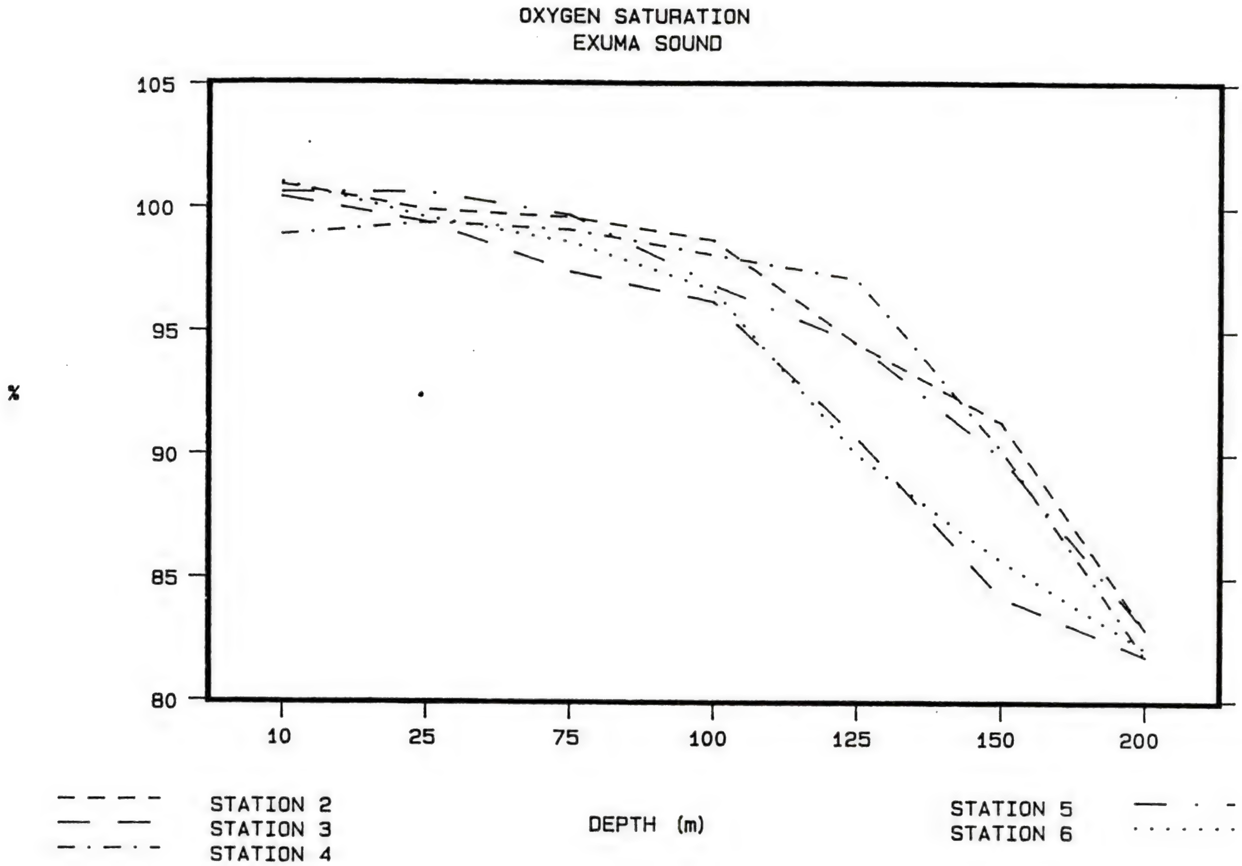


Figure 9. Oxygen concentration as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



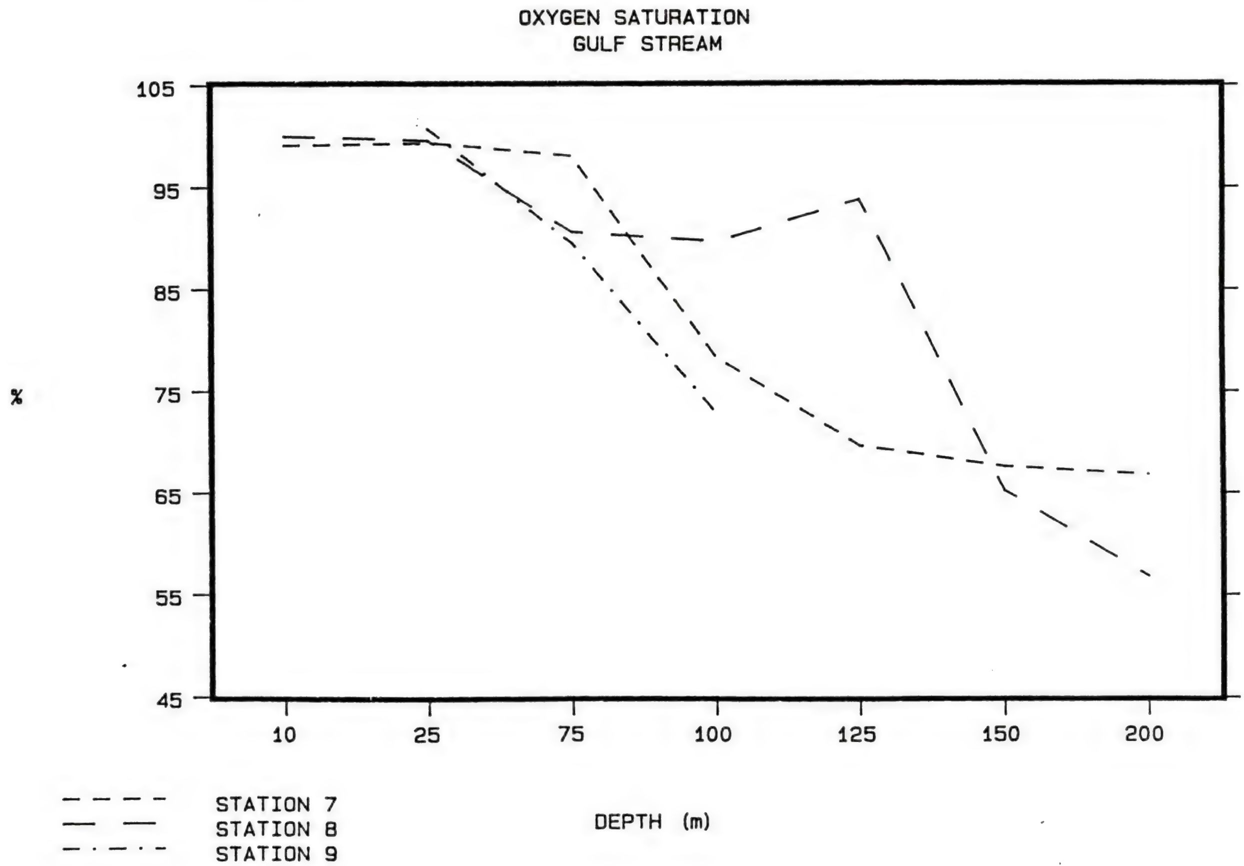
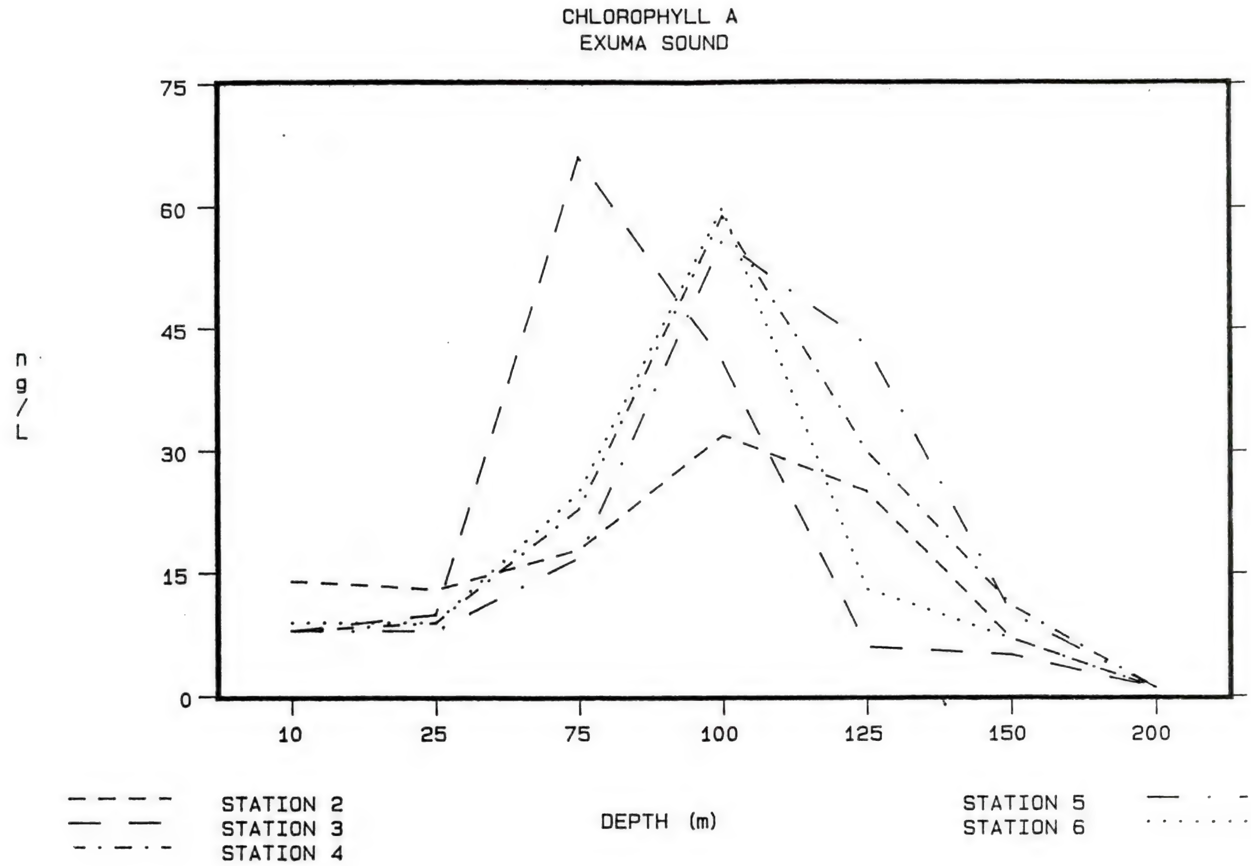


Figure 10. Oxygen saturation as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



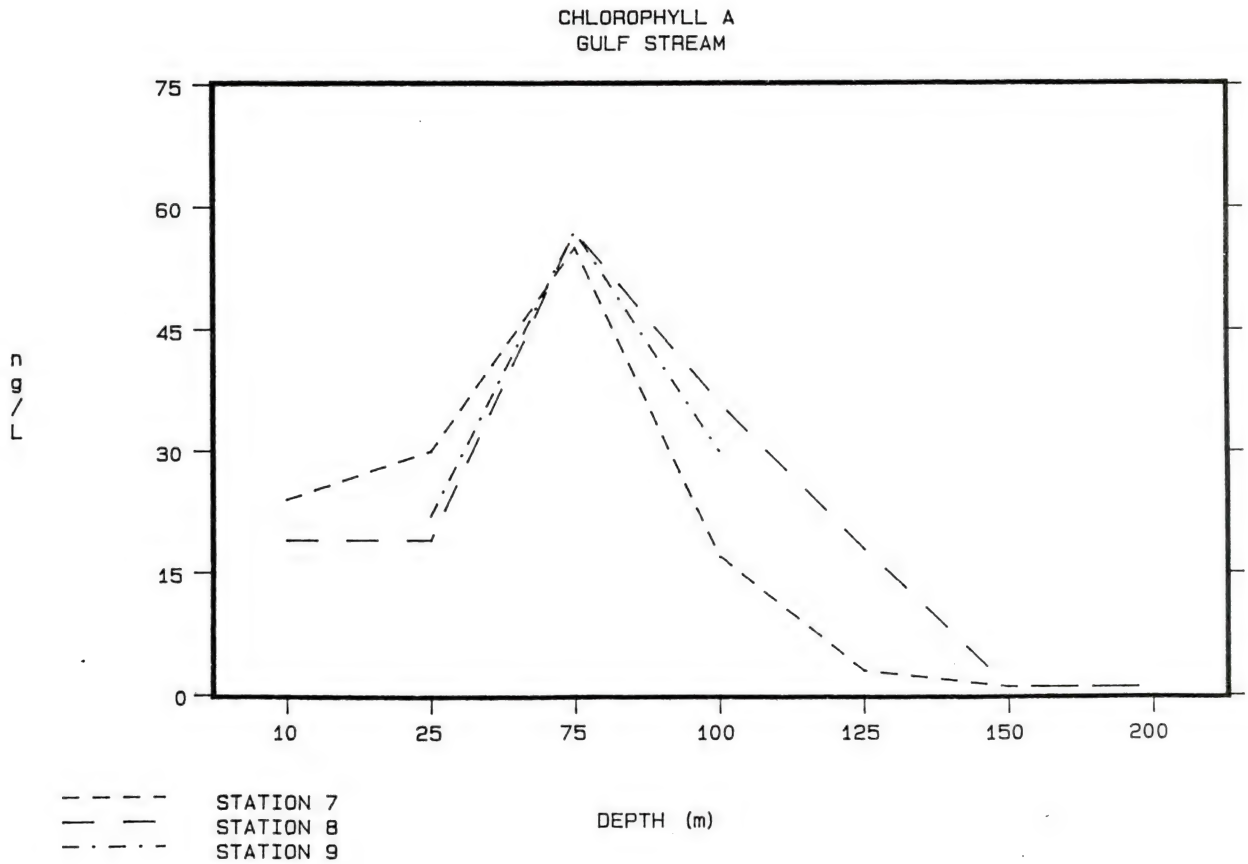


Figure 11. Chlorophyll-a concentration as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).

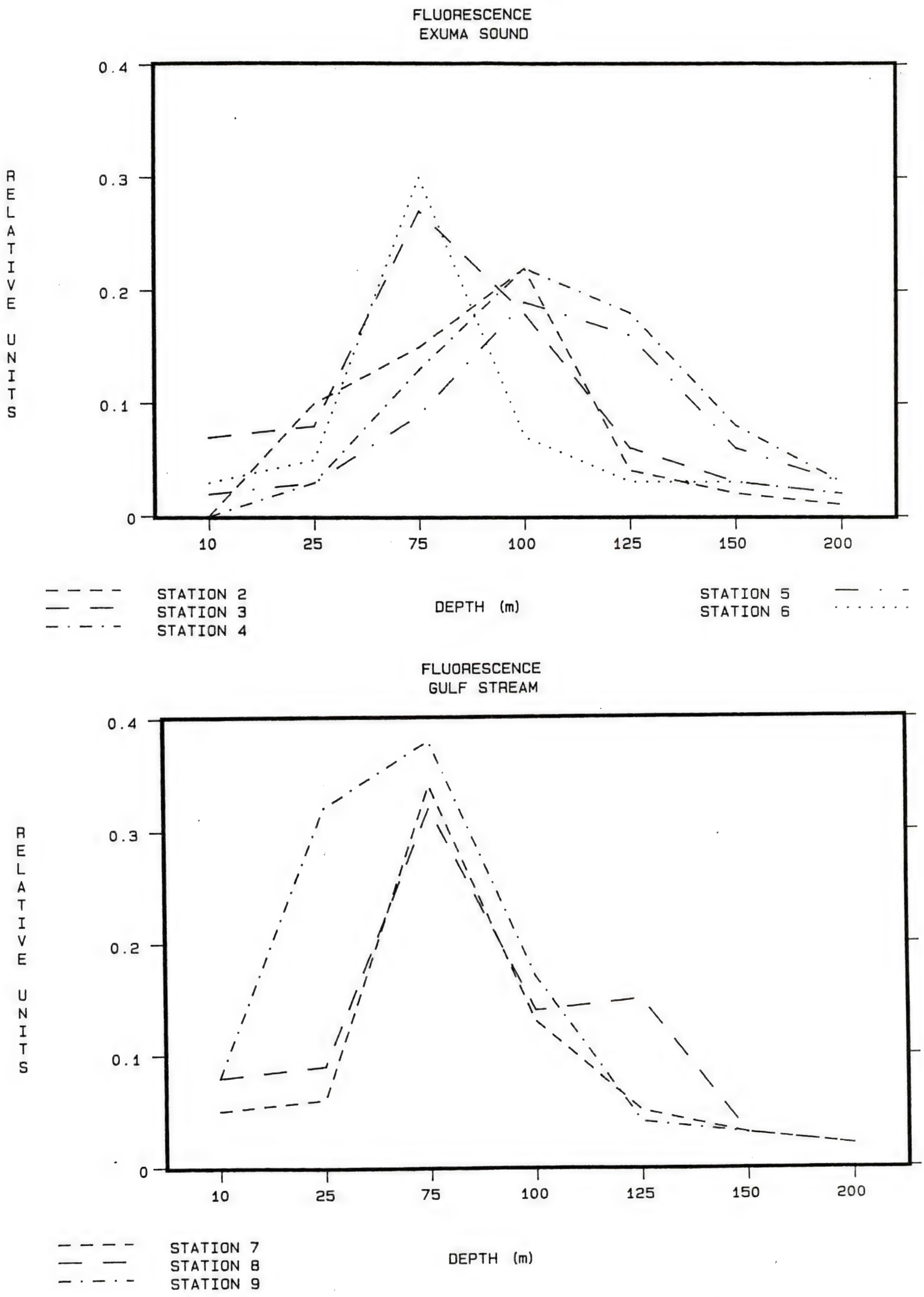


Figure 12. Fluorescence concentration as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).

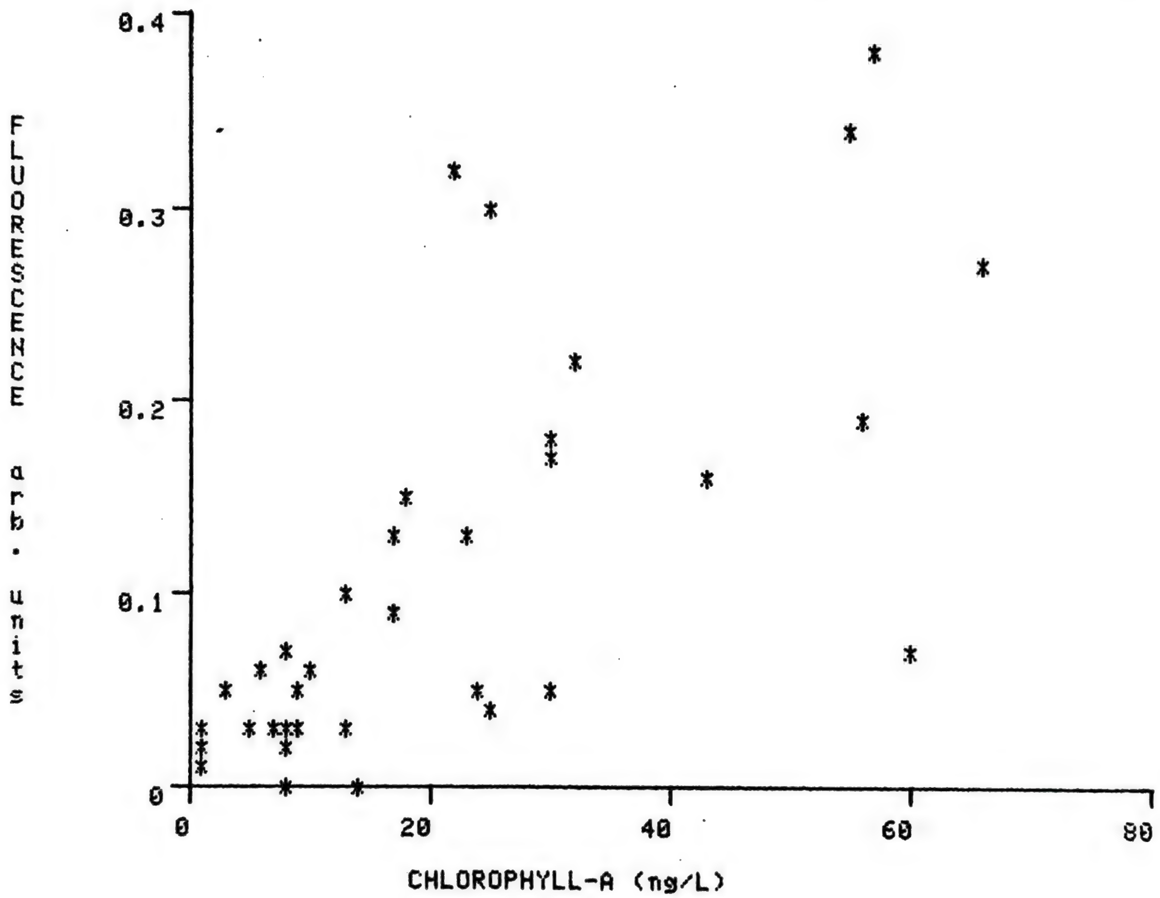
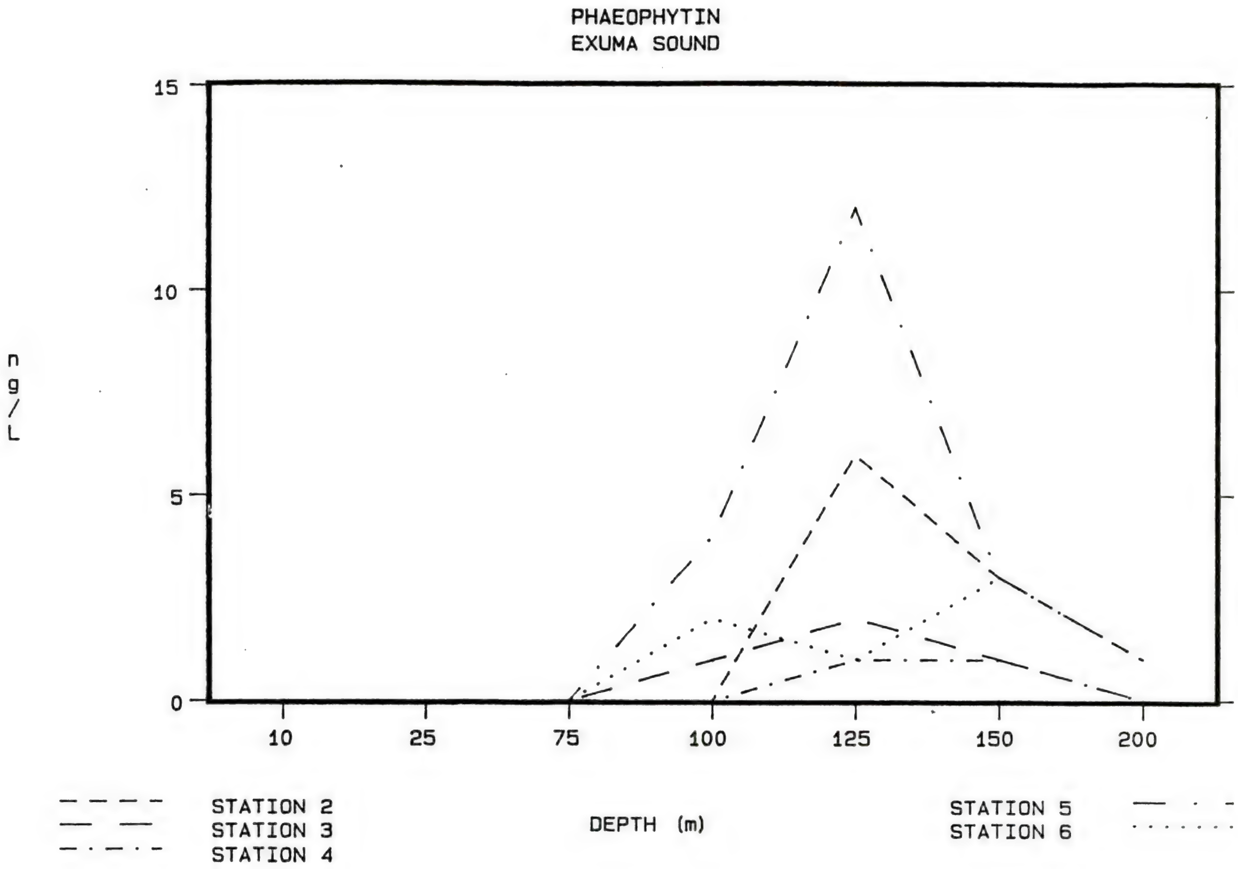


Figure 13. Scatter plot showing fluorescence vs. chlorophyll-a concentrations.



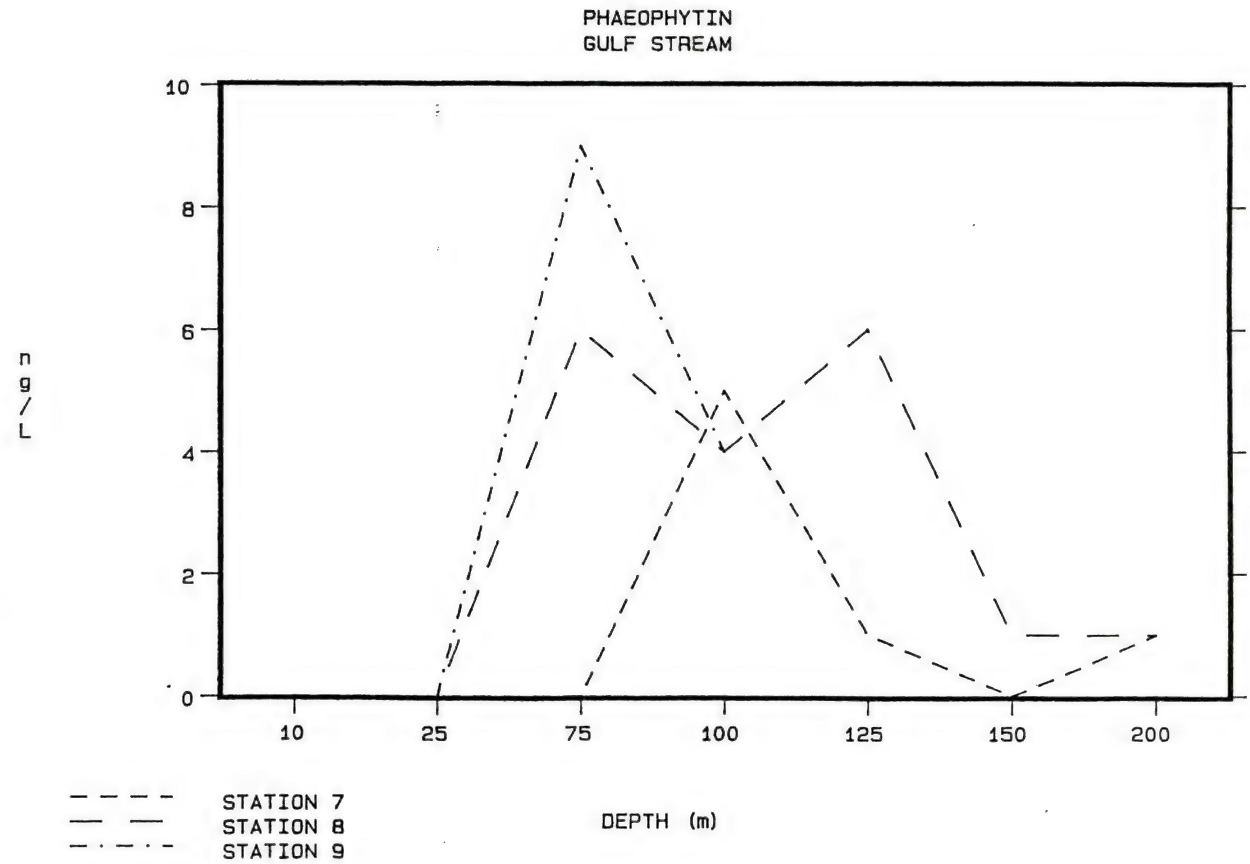
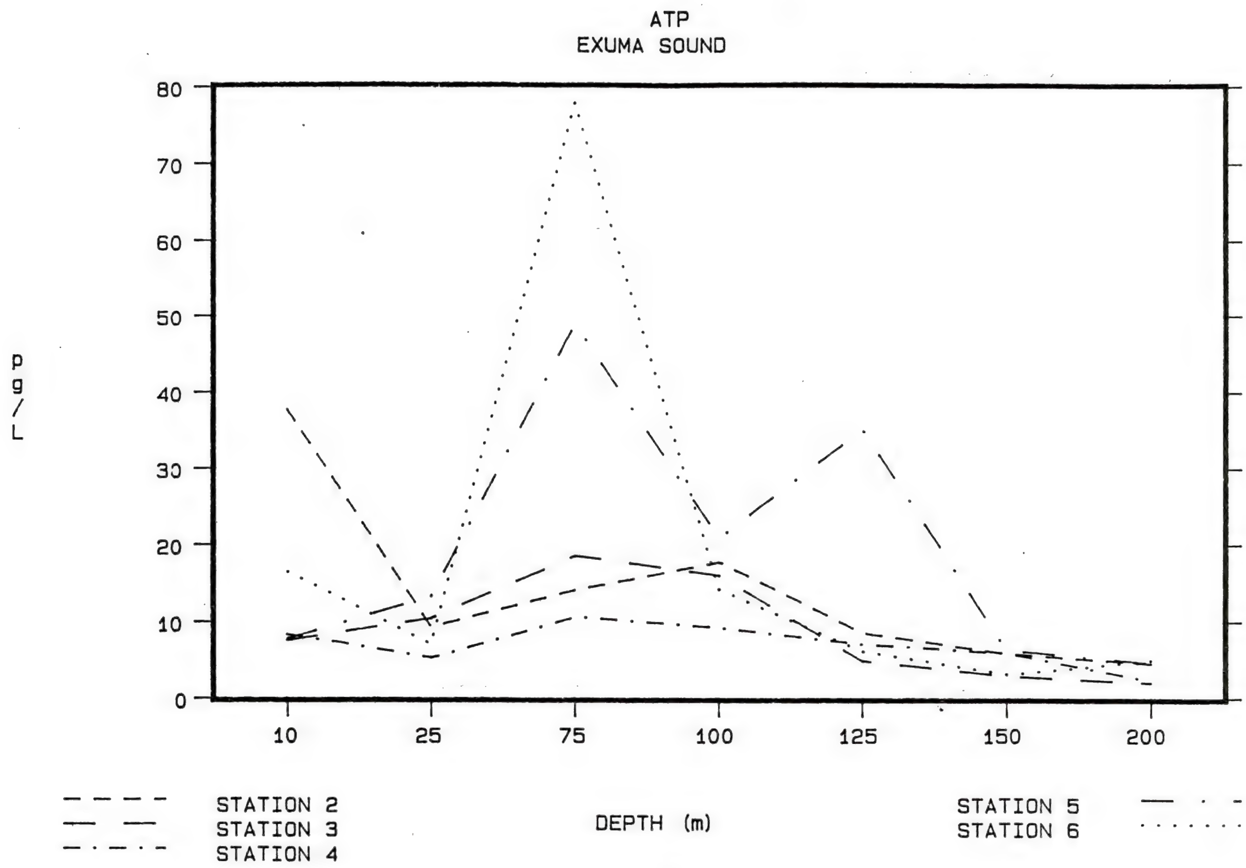


Figure 14. Phaeophytin concentrations as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



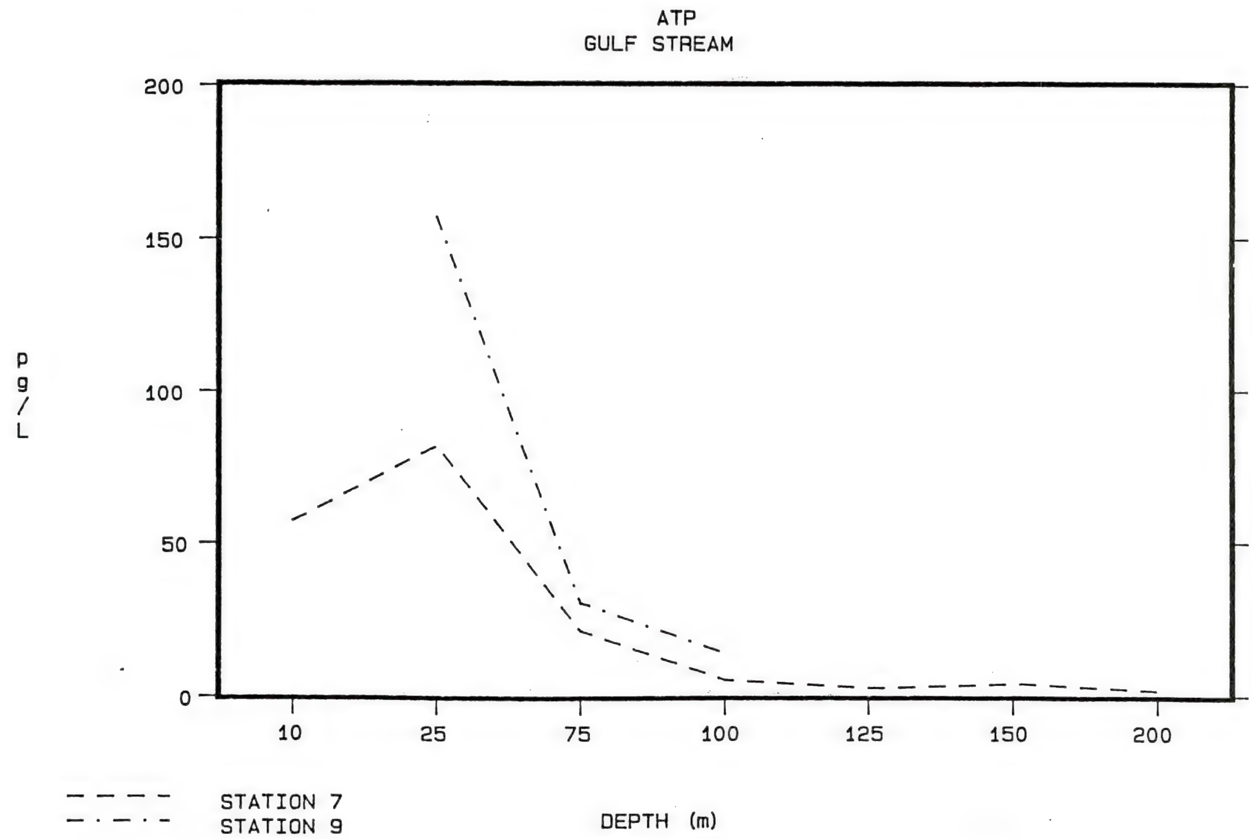


Figure 15. ATP concentrations as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).

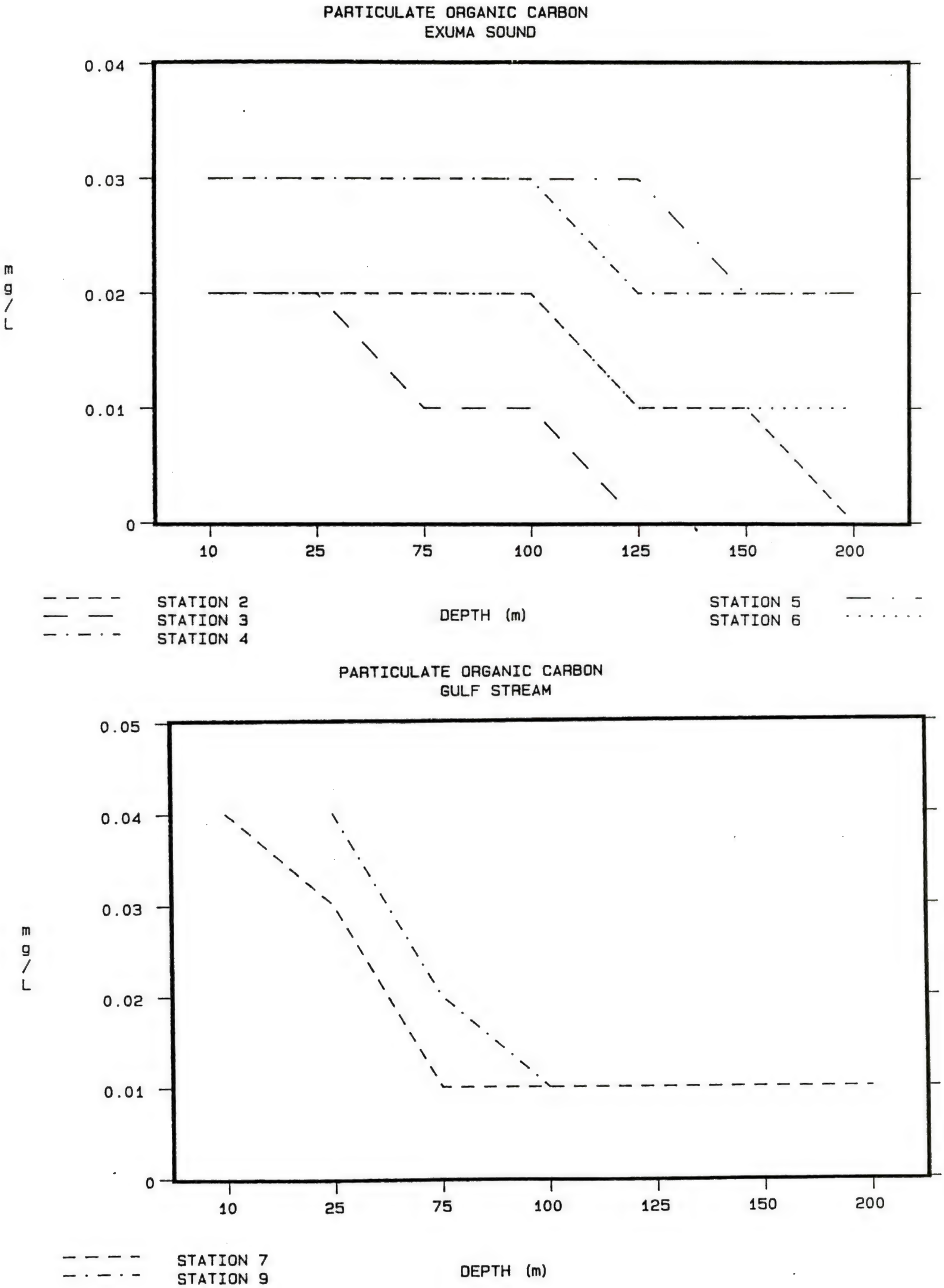
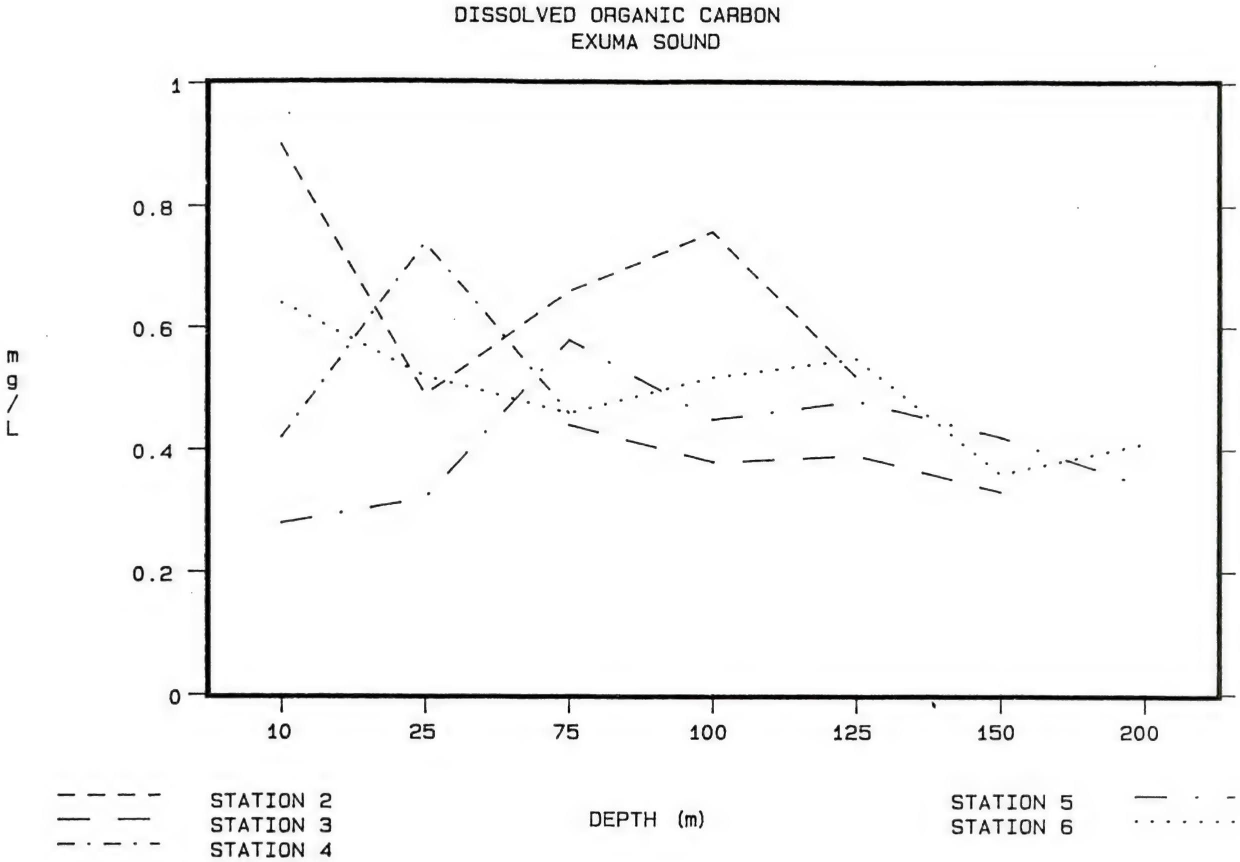


Figure 16. Particulate organic carbon concentrations as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).



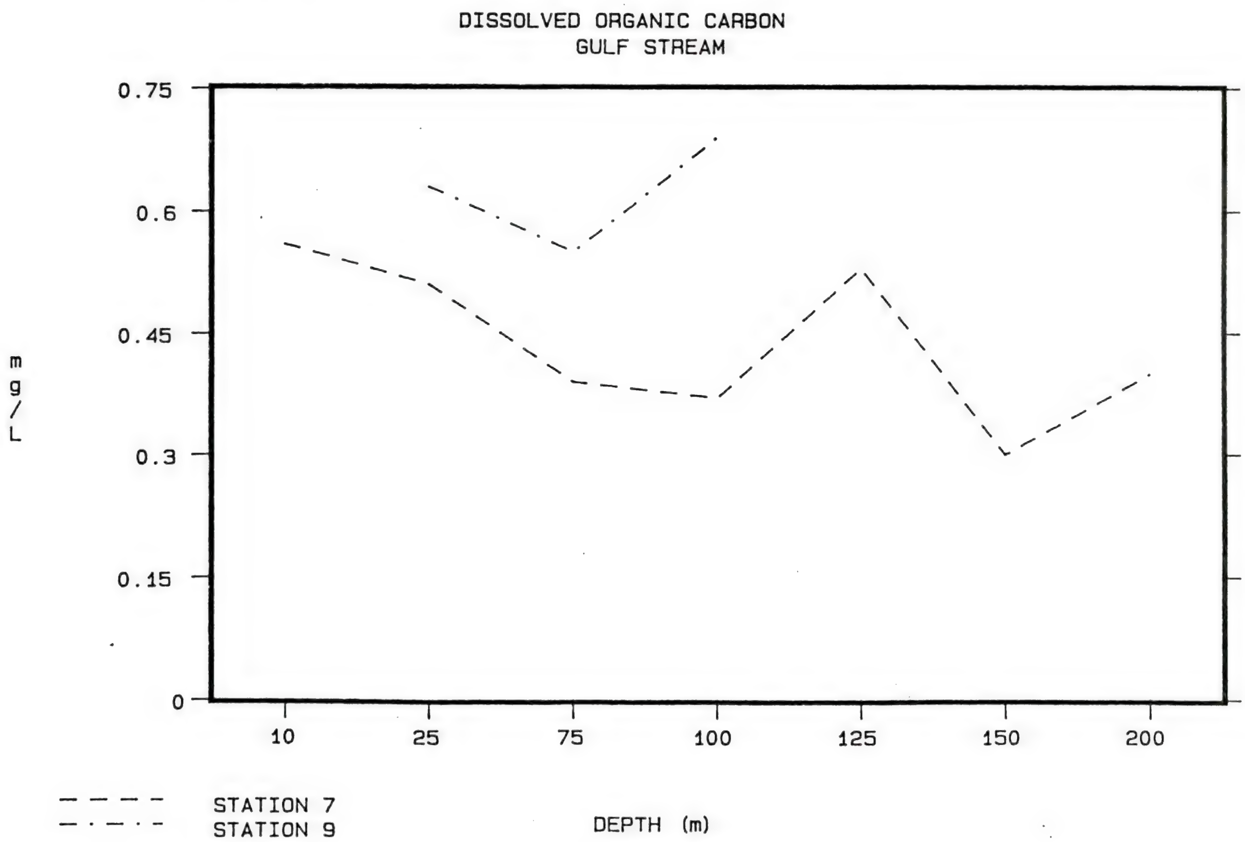


Figure 17. Dissolved organic carbon concentrations as a function of depth in Exuma Sound (top) and in the Straits of Florida (bottom).

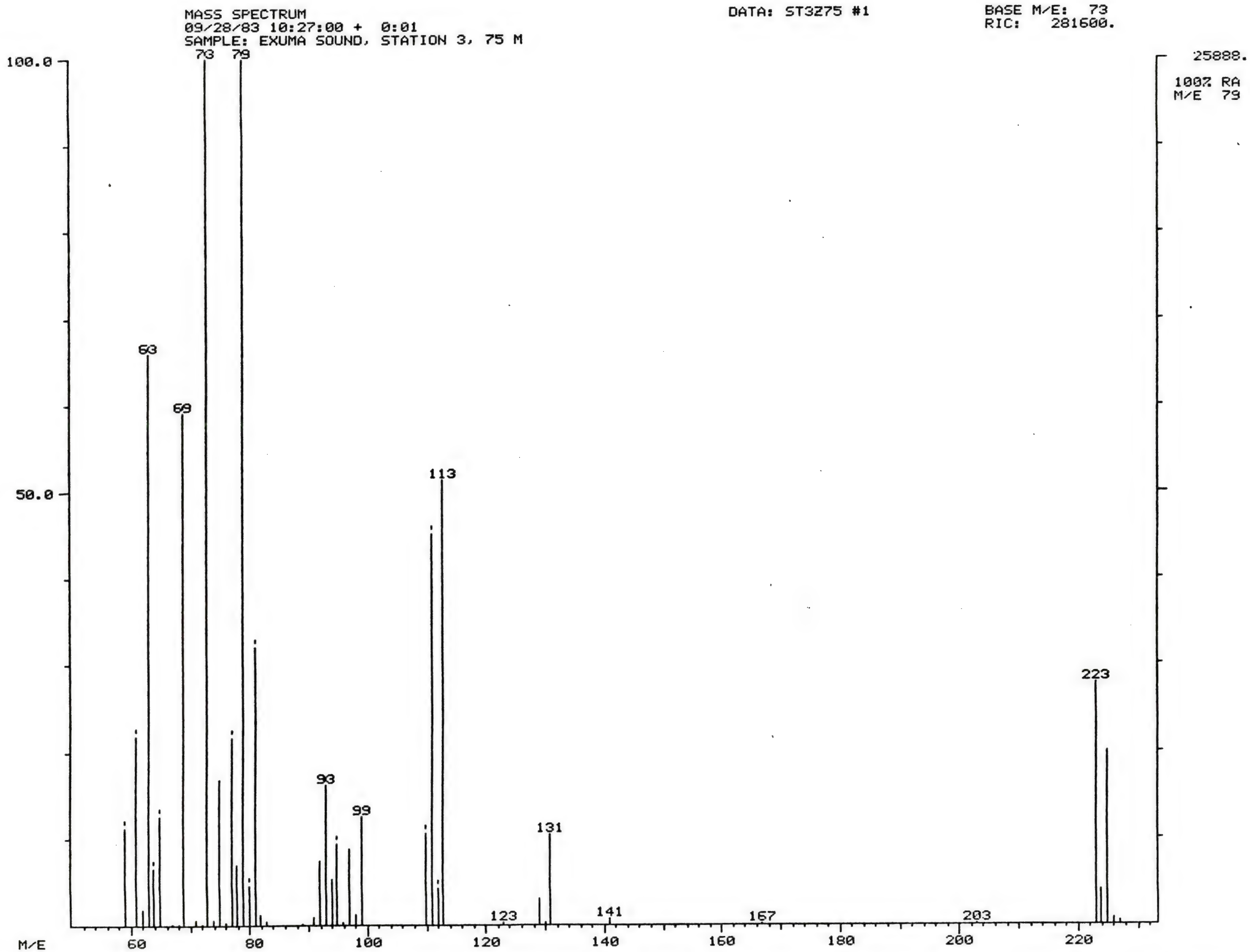


Figure 18. Typical pyrolysis-mass spectrum obtained from the nonvolatile organics in the water samples. This sample was obtained from 75-m depth at Sation 3 in Exuma Sound. The abscissa is in atomic mass per charge units. The ordinate is normalized to the fragment with a mass of 79 and is proportional to the quantity of each fragment present. Quantification is done with digital counts, and RIC in the upper-right corner refers to the total counts that were present in this sample.

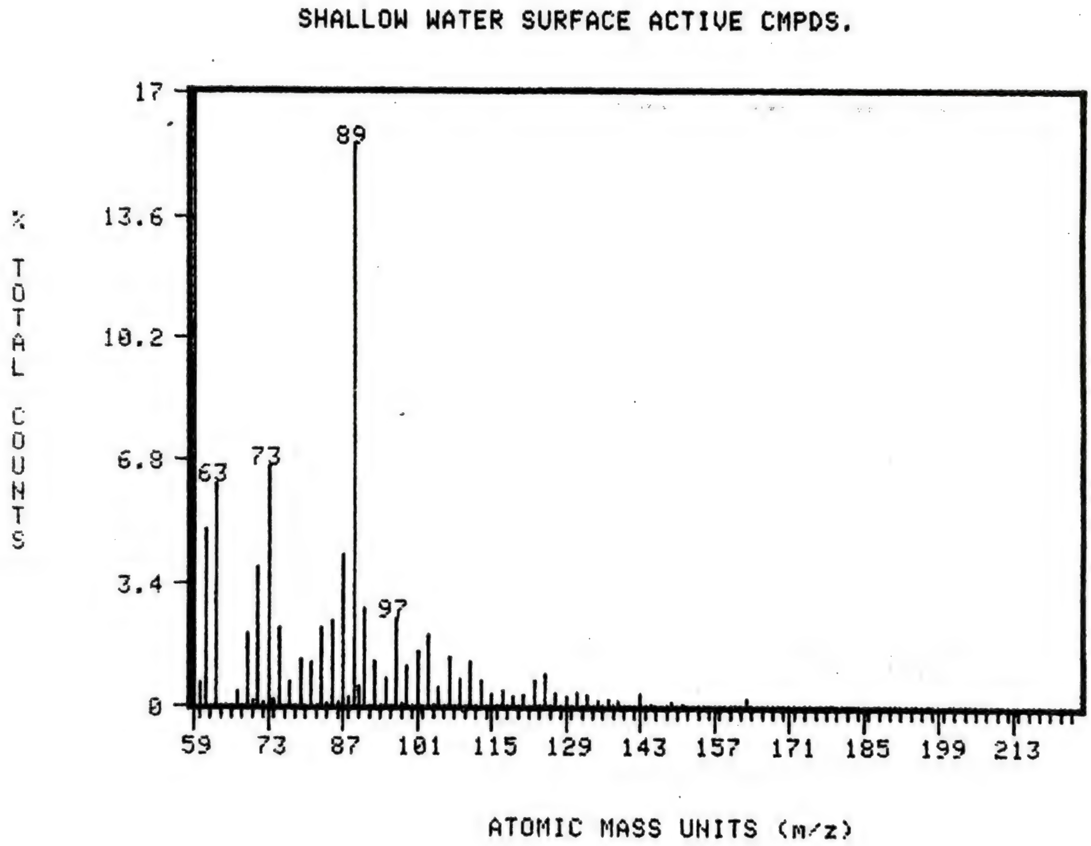


Figure 19. Pyrolysis-mass spectrum surface active material from 10-m depth. This is an average of all the analyzed samples from that depth. The abscissa is atomic masses per charge. The ordinate gives the relative quantity of each fragment to the total of all the fragments present.

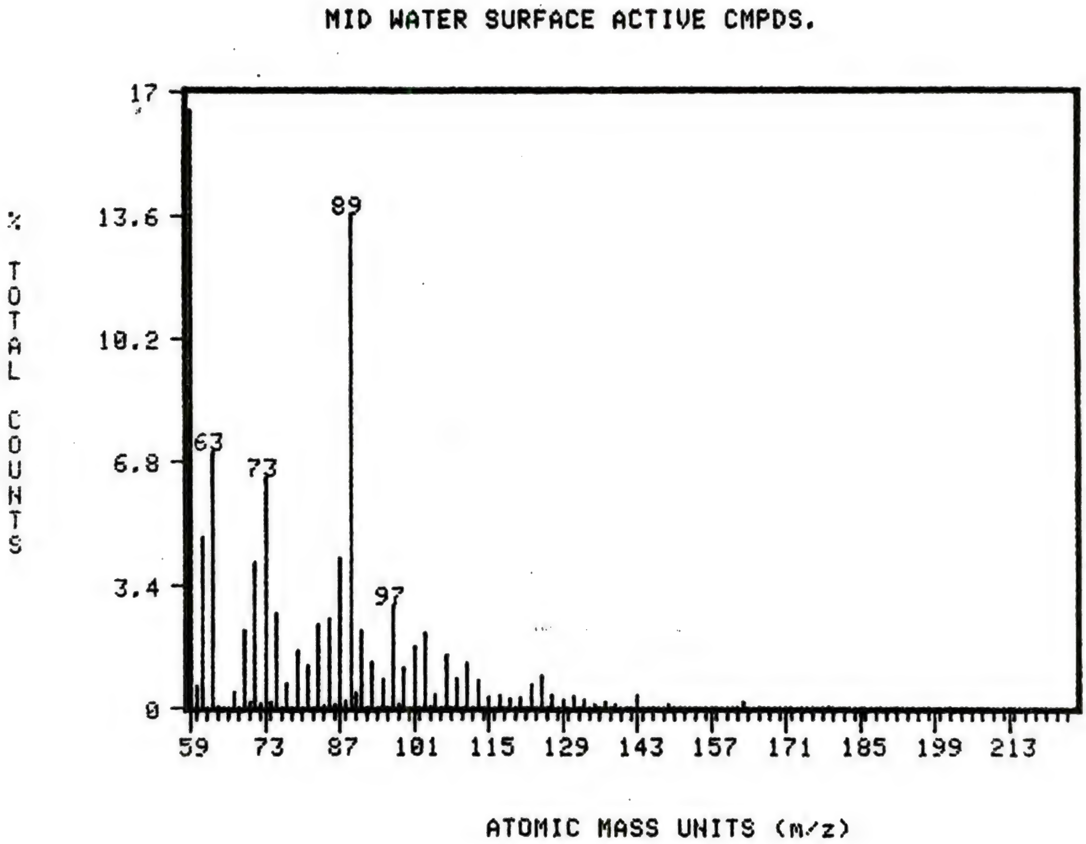


Figure 20. Same as Figure 30, but for the average of all the samples analyzed from a depth of 75 m.

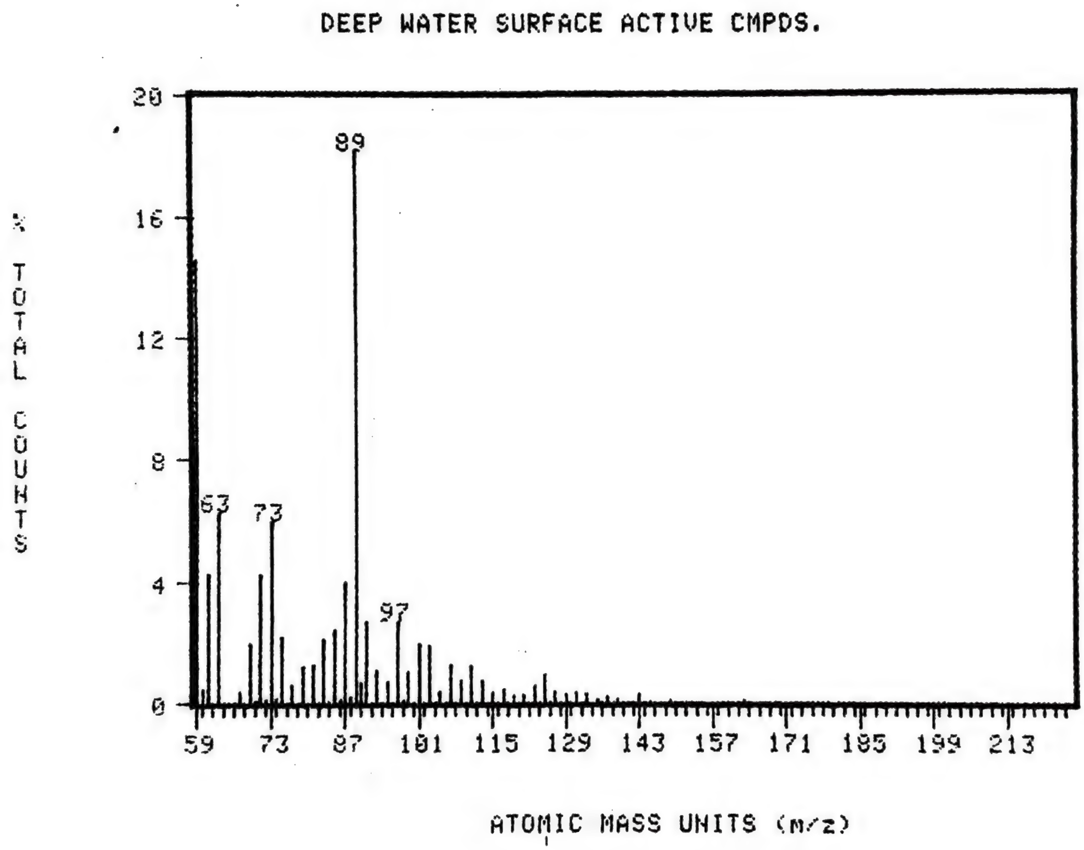


Figure 21. Same as Figure 30, but for the average of all samples analyzed from a depth of 200 m.

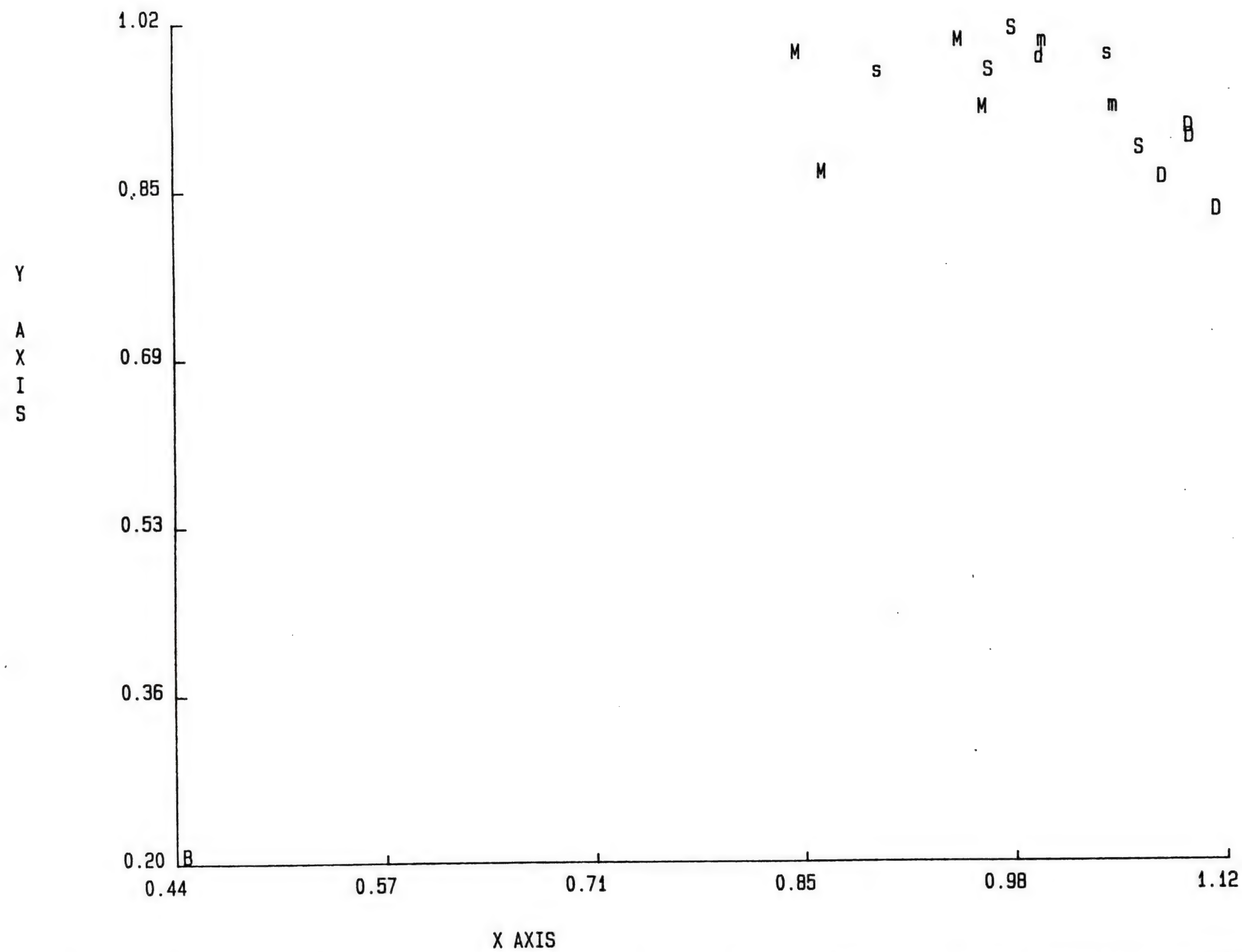
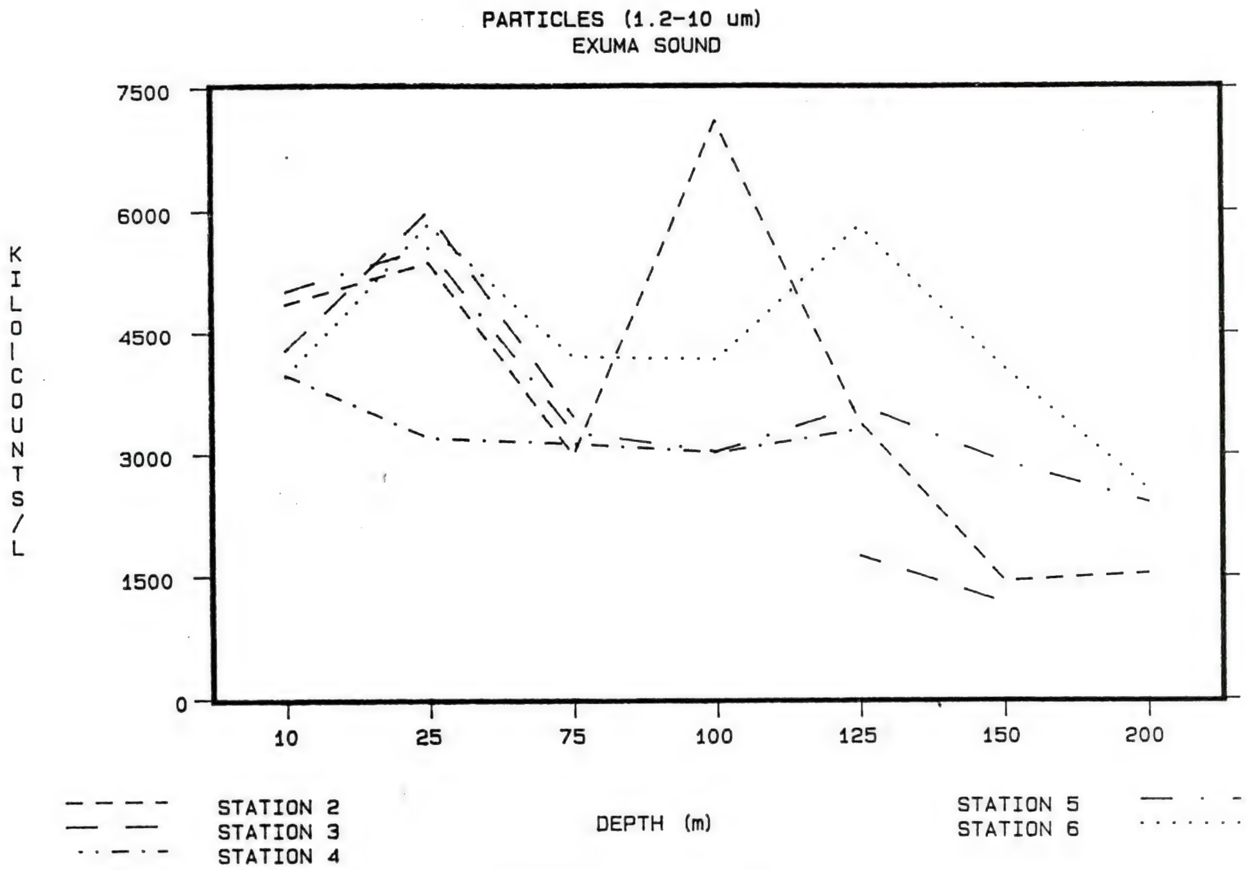


Figure 22. *Nonlinear map showing in two dimensions the distance between all the similarity coefficients obtained from the analyses of the surface active material. The closer the symbols are, the greater is the similarity between the samples they represent. The symbols stand for the following samples:*

B. Blank
S. Shallow water samples from Exuma Sound
s. Shallow water samples from the Straits of Florida
M. Mid-water sample from Exuma Sound
m. Mid-water sample from the Straits of Florida
D. Deep-water sample from Exuma Sound
d. deep-water sample from the Straits of Florida



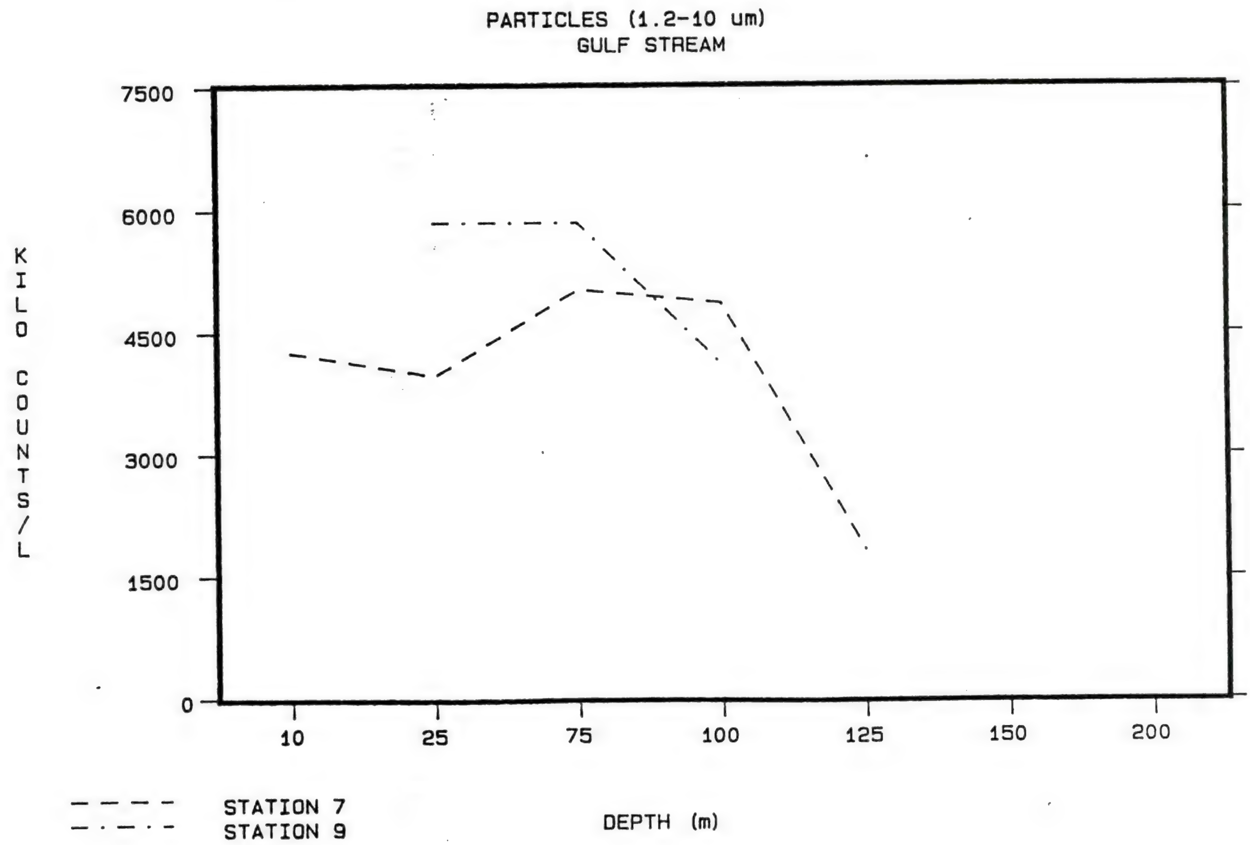
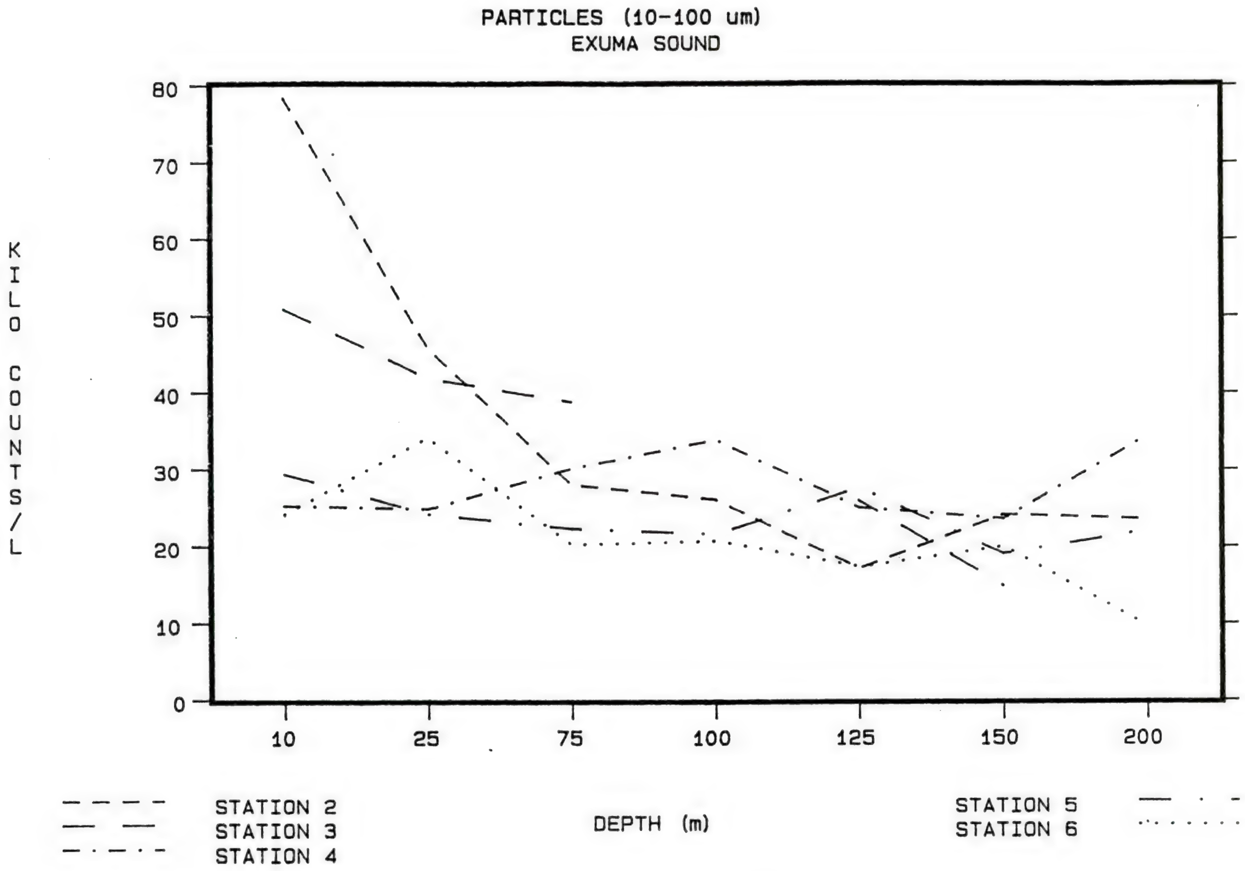


Figure 23. Small (1-10 μm diameter) particle counts from Exuma Sound (top) and the Straits of Florida (bottom).



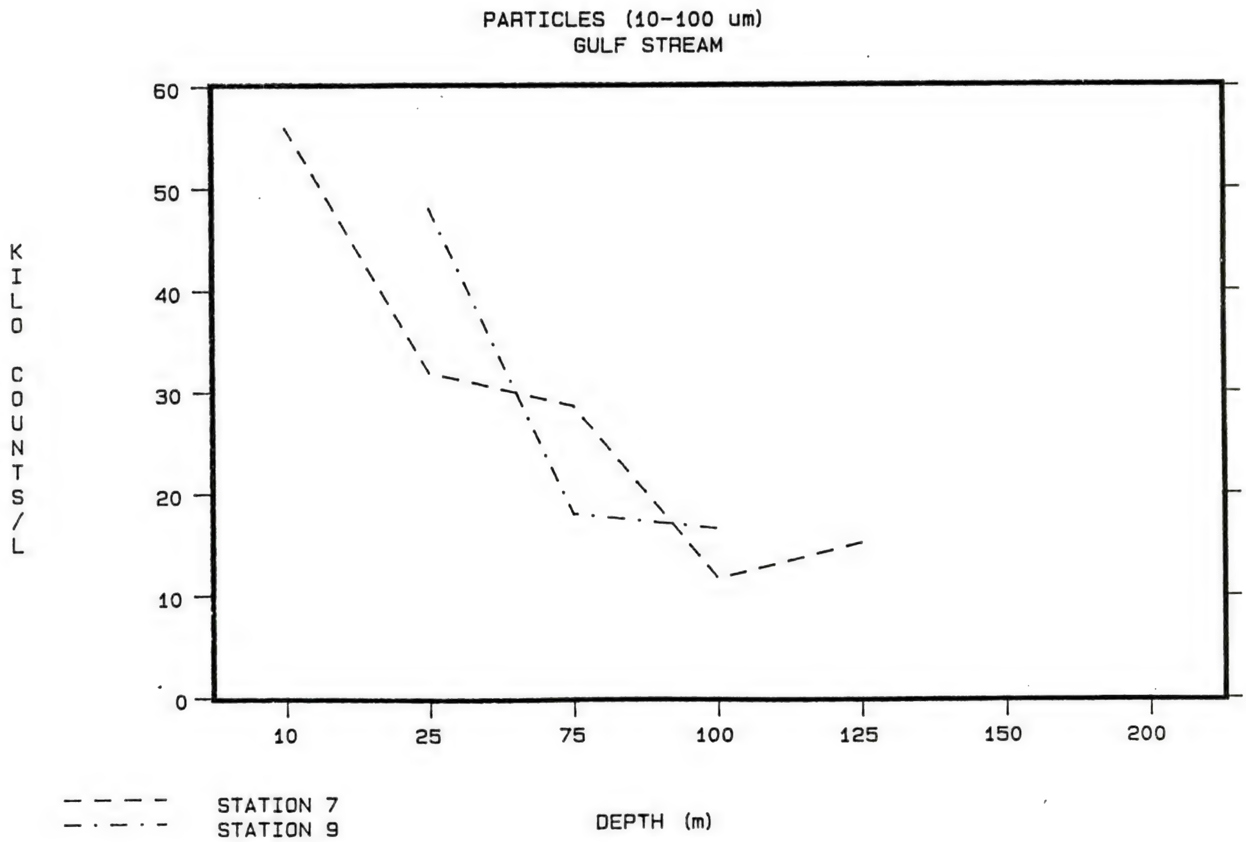


Figure 24. Large (10-100 µm diameter) particle counts from Exuma Sound (top) and the Straits of Florida (bottom).

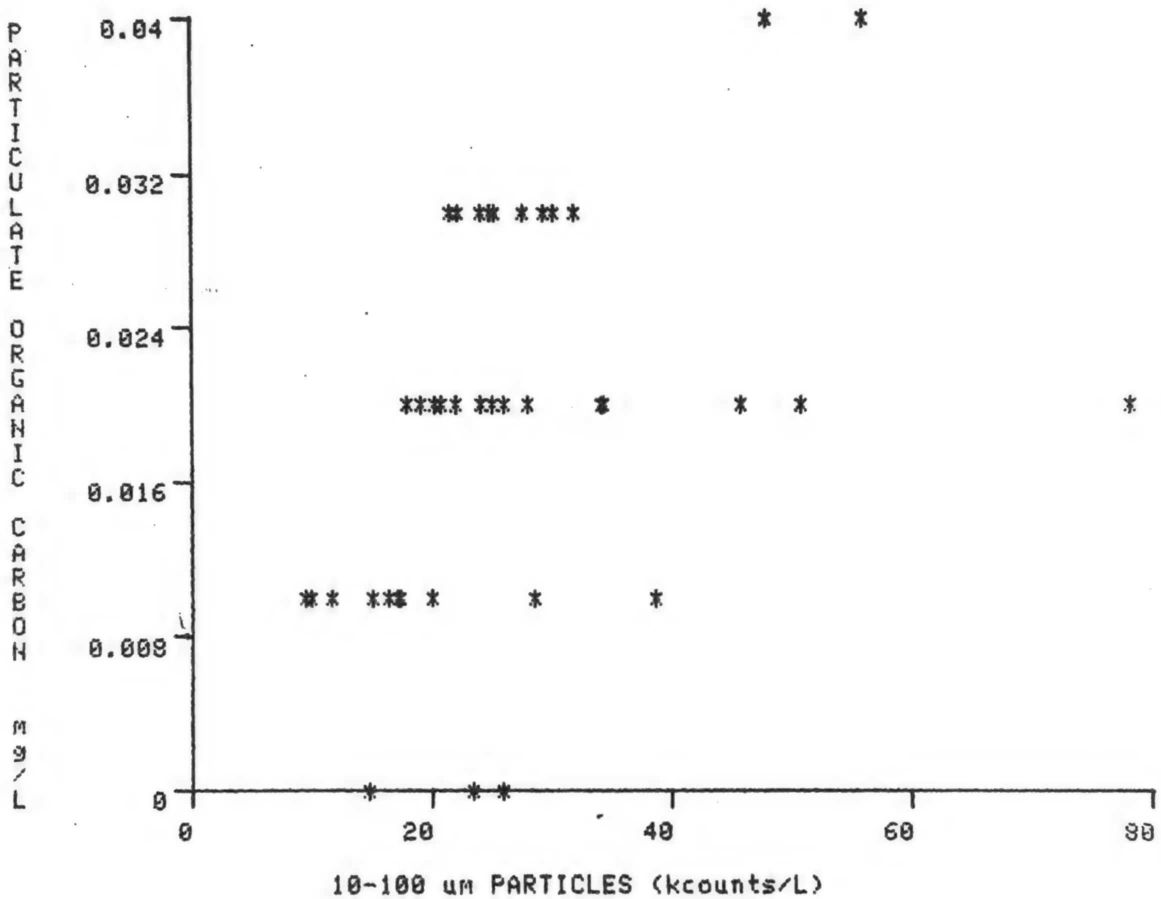
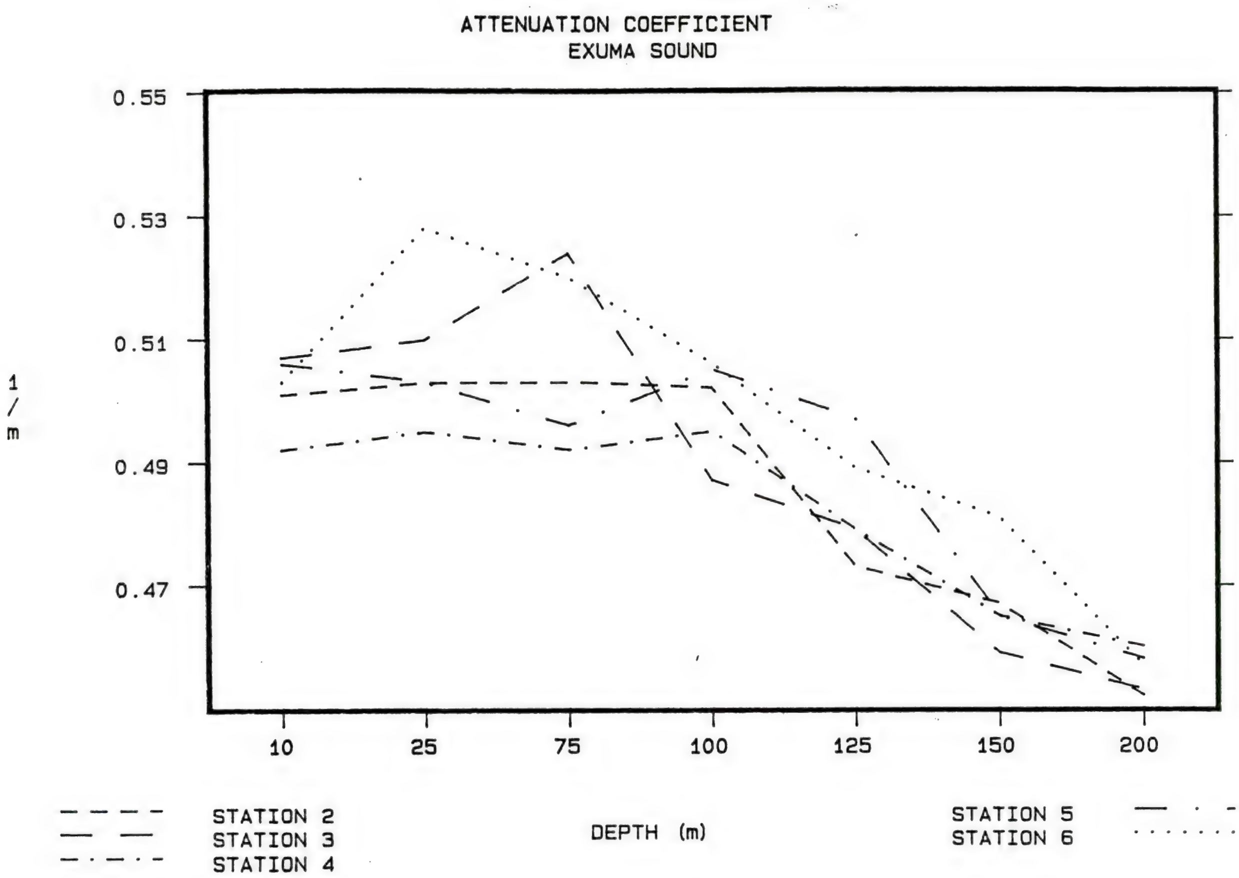


Figure 25. Scatter plot of large particle counts vs. particulate organic carbon concentrations.



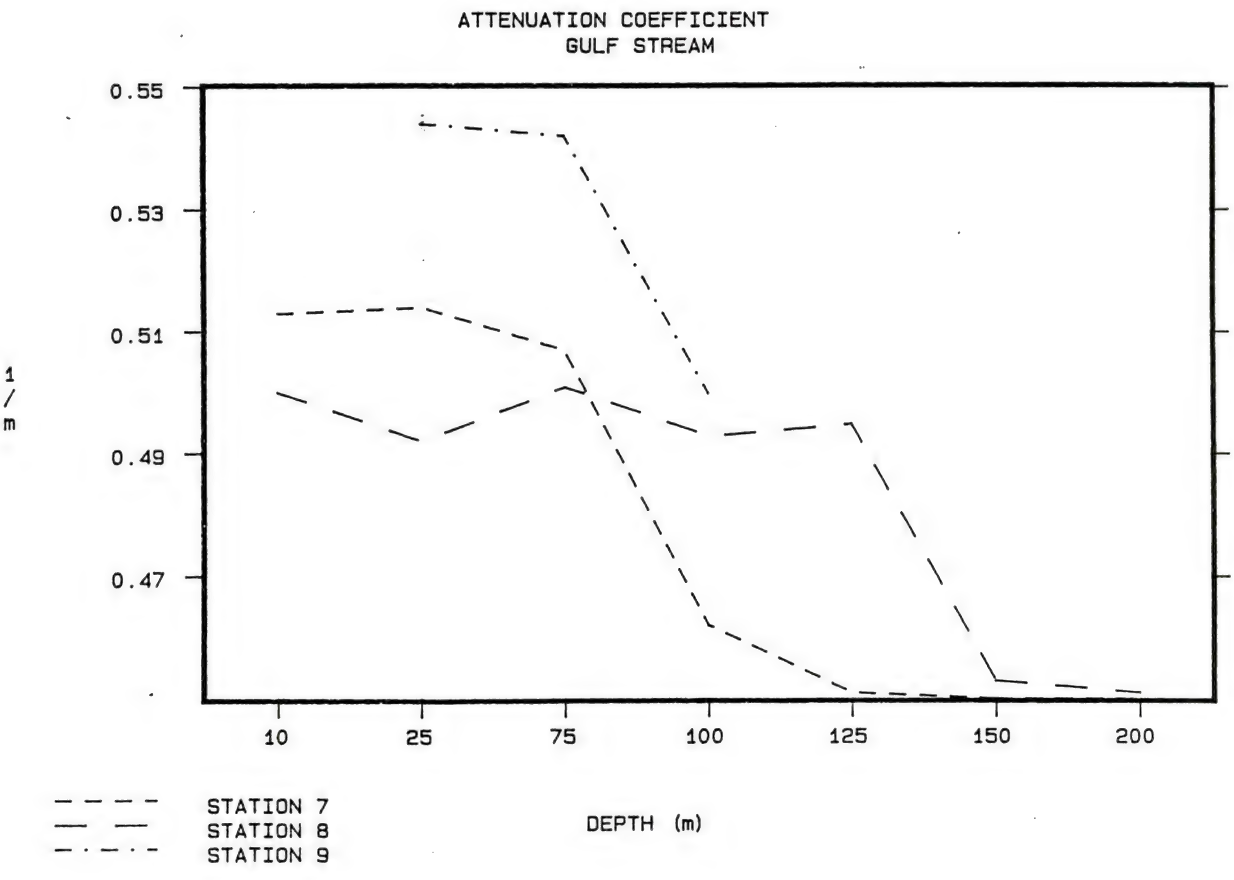


Figure 26. Beam attenuation coefficient from Exuma Sound (top) and the Straits of Florida (bottom).

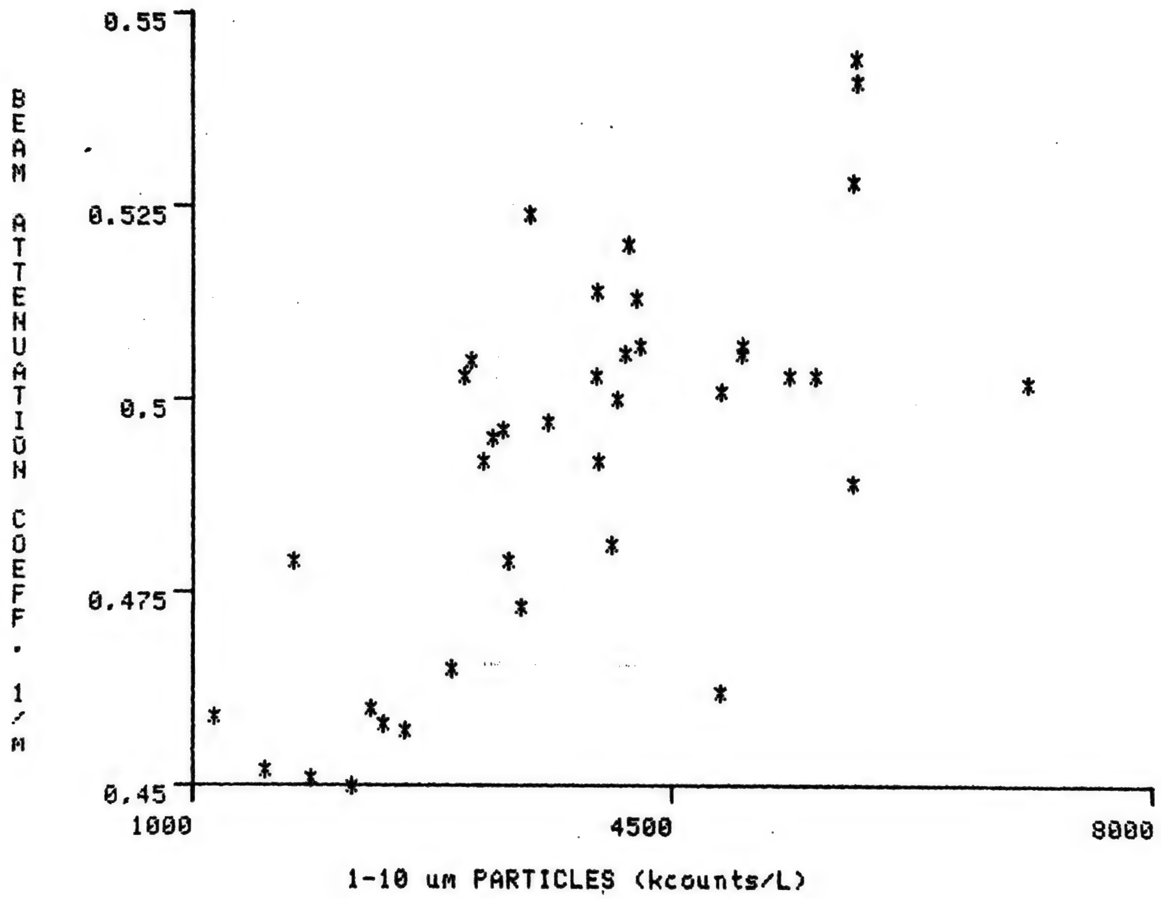


Figure 27. Scatter plot of the beam attenuation coefficient vs. small particle counts.

APPENDIX

Gas Parameters

Sample Number	Depth (m)	Oxygen (ml/L)	Oxygen Saturation (%)	Nitrogen (ml/L)	Nitrogen Saturation (%)
Station 2					
1	10	4.84	100.9	8.88	100.0
2	25	4.86	101.2	9.03	101.6
3	75	4.78	99.0	8.80	99.0
4	100	4.74	98.7	8.79	98.8
5	125	4.55	94.5	8.60	96.5
6	150	4.41	91.3	8.98	100.5
7	200	4.14	82.9	9.28	100.8
Station 3					
8	10	4.80	100.4	8.86	100.0
9	25	4.76	99.4	8.96	101.0
10	75	4.68	97.5	8.83	99.3
11	100	4.52	96.2	8.79	98.6
12	125	4.38	90.7	8.84	98.9
13	150	4.11	84.2	8.96	99.3
14	200	4.11	81.8	9.22	99.5
Station 4					
15	10	4.71	98.9	8.69	98.4
16	25	4.74	99.4	8.68	98.2
17	75	4.74	99.1	8.82	99.5
18	100	4.70	98.1	8.61	97.0
19	125	4.62	97.1	8.57	96.4
20	150	4.39	90.2	8.93	99.2
21	200	4.09	81.8	9.14	99.2
Station 5					
22	10	4.76	100.6	8.97	102.1
23	25	4.78	100.6	8.77	99.5
24	75	4.76	99.7	8.73	98.6
25	100	4.65	96.9	8.76	98.6
26	125	4.53	94.5	8.79	98.9
27	150	4.36	89.9	8.98	100.1
28	200	4.13	82.9	9.13	99.4

Gas Parameters (cont'd)

Sample Number	Depth (m)	Oxygen (ml/L)	Oxygen Saturation (%)	Nitrogen (ml/L)	Nitrogen Saturation (%)
		Station 6			
29	10	4.80	101.0	8.63	98.0
30	25	4.77	99.6	8.77	98.9
31	75	4.73	98.6	8.92	100.4
32	100	4.65	96.7	8.74	98.1
33	125	4.34	90.0	8.93	100.0
34	150	4.17	85.7	8.88	98.7
35	200	4.10	82.1	9.12	99.0
		Station 7			
36	10	4.65	99.1	8.61	98.8
37	25	4.66	99.3	8.85	101.5
38	75	4.60	98.0	8.60	98.6
39	100	3.73	78.3	8.83	100.0
40	125	3.44	69.6	9.06	99.3
41	150	3.39	67.6	9.20	99.6
42	200	3.53	66.8	9.77	100.8
		Station 8			
43	10	4.69	100.0	--	--
44	25	4.68	99.5	--	--
45	75	4.28	90.6	--	--
46	100	4.41	89.7	--	--
47	125	4.78	93.8	--	--
48	150	3.45	65.2	--	--
49	200	3.17	56.8	--	--
		Station 9			
50	10	--	--	--	--
51	25	4.84	100.7	9.01	101.1
52	75	4.56	89.5	9.39	100.1
53	100	3.84	72.8	9.86	101.8
54	125	--	--	--	--
55	150	2.99	49.7	10.99	100.8
56	200	--	--	--	--

Biological Parameters

Sample Number	Depth (m)	Fluorescence (arb. units)	Chlorophyll (ng/L)	Phaeophytin (ng/L)	ATP (pg/L)
		Station 2			
1	10	0.00	14	0	37.7
2	25	0.10	13	0	9.4
3	75	0.15	18	0	14.1
4	100	0.22	32	0	17.8
5	125	0.04	25	6	8.6
6	150	0.02	7	3	5.9
7	200	0.01	1	1	4.5
		Station 3			
8	10	0.07	8	0	7.6
9	25	0.08	10	0	10.5
10	75	0.27	66	0	18.6
11	100	0.18	41	1	16.0
12	125	0.06	6	2	4.9
13	150	0.03	5	1	2.9
14	200	0.02	1	0	2.0
		Station 4			
15	10	0.00	8	0	8.3
16	25	0.03	9	0	5.3
17	75	0.13	23	0	10.7
18	100	0.22	59	0	9.2
19	125	0.18	30	1	7.1
20	150	0.08	11	1	5.9
21	200	0.03	1	0	2.3
		Station 5			
22	10	0.02	8	0	7.8
23	25	0.03	8	0	13.3
24	75	0.09	17	0	49.0
25	100	0.19	56	4	20.9
26	125	0.16	43	12	35.1
27	150	0.06	10	3	6.3
28	200	0.03	1	1	4.6

Biological Parameters (cont'd)

Sample Number	Depth (m)	Fluorescence (arb. units)	Chlorophyll (ng/L)	Phaeophytin (ng/L)	ATP (pg/L)
		Station 6			
29	10	0.03	9	0	16.5
30	25	0.05	9	0	7.1
31	75	0.30	25	0	77.9
32	100	0.07	60	2	14.2
33	125	0.03	13	1	6.2
34	150	0.03	7	3	3.2
35	200	0.02	1	1	5.0
		Station 7			
36	10	0.05	24	0	57.3
37	25	0.05	30	0	82.0
38	75	0.34	55	0	21.1
39	100	0.13	17	4	5.4
40	125	0.05	3	1	2.7
41	150	0.03	1	0	4.2
42	200	0.02	1	1	1.7
		Station 8			
43	10	0.08	19	0	--
44	25	0.09	19	0	--
45	75	0.32	57	6	--
46	100	0.14	36	4	--
47	125	0.14	18	6	--
48	150	0.03	1	1	--
49	200	0.02	1	1	--
		Station 9			
50	10	0.08	--	--	--
51	25	0.32	22	0	157.0
52	75	0.38	57	9	30.4
53	100	0.17	30	4	14.0
54	125	0.04	--	--	--
55	150	0.03	2	2	1.5
56	200	--	--	--	--

Particle Parameters

Sample Number	Depth (m)	Counts (10^3/L) 1.2 - 10 μm	10 - 100 μm
Station 2			
1	10	4861	78.3
2	25	5366	45.9
3	75	2991	28.0
4	100	7094	26.1
5	125	3403	17.2
6	150	1441	24.2
7	200	1537	23.5
Station 3			
8	10	4279	50.9
9	25	5992	41.9
10	75	3471	38.8
11	100	--	--
12	125	1749	26.0
13	150	1167	14.9
14	200	--	--
Station 4			
15	10	3970	25.3
16	25	3195	24.9
17	75	3129	30.2
18	100	3026	33.9
19	125	3314	25.1
20	150	--	23.6
21	200	2309	34.4
Station 5			
22	10	5018	29.4
23	25	5549	24.2
24	75	3269	22.3
25	100	3037	21.6
26	125	3605	27.7
27	150	2900	19.1
28	200	2399	22.1

Particle Parameters (cont'd)

Sample Number	Depth (m)	Counts (10^3/L) 1.2 - 10 μm	10 - 100 μm
		Station 6	
29	10	3953	24.2
30	25	5830	34.2
31	75	4192	20.3
32	100	4168	20.8
33	125	5824	17.4
34	150	4064	20.1
35	200	2559	9.6
		Station 7	
36	10	4254	56.0
37	25	3959	31.9
38	75	5024	28.6
39	100	4859	11.7
40	125	1869	15.2
41	150	--	--
42	200	2165	10.0
		Station 8	
43	10	--	--
44	25	--	--
45	75	--	--
46	100	--	--
47	125	--	--
48	150	--	--
49	200	--	--
		Station 9	
50	10	--	--
51	25	5846	48.1
52	75	5849	18.0
53	100	4111	16.5
54	125	--	--
55	150	--	--
56	200	--	--

Hydrographic Parameters

Sample Number	Depth (m)	Temperature (^{o}C)	Salinity ($^{o}/oo$)	
		Station 2		
1	10	23.62	36.619	24.98
2	25	23.62	36.615	24.98
3	75	23.60	36.621	25.00
4	100	23.51	36.627	25.10
5	125	23.40	36.660	25.03
6	150	23.18	36.671	25.35
7	200	21.28	36.770	25.80
		Station 3		
8	10	23.81	36.649	24.95
9	25	23.72	36.648	24.97
10	75	23.54	36.657	25.03
11	100	23.41	36.655	25.07
12	125	23.22	36.663	25.15
13	150	22.54	36.787	25.43
14	200	20.92	36.757	25.86
		Station 4		
15	10	24.01	36.628	24.82
16	25	23.92	36.624	24.88
17	75	23.75	36.641	24.96
18	100	23.66	36.647	24.98
19	125	23.54	36.649	25.02
20	150	22.77	36.697	25.18
21	200	21.25	36.759	25.75
		Station 5		
22	10	24.37	36.629	24.75
23	25	24.14	36.621	24.80
24	75	23.87	36.615	24.88
25	100	23.60	36.636	24.93
26	125	23.60	36.671	25.10
27	150	22.92	36.725	25.25
28	200	21.44	36.779	25.75
		Station 6		
29	10	24.15	36.655	24.83
30	25	23.99	36.655	24.90
31	75	23.71	36.647	25.00

Sample Number	Depth (m)	Temperature (^oC)	Salinity ($^o/oo$)	
32	100	23.44	36.660	25.06
33	125	23.25	36.716	25.12
34	150	22.75	36.781	25.30
35	200	21.27	36.768	25.75
		Station 7		
36	10	25.06	36.095	24.20
37	25	25.06	36.149	24.25
38	75	25.03	36.154	24.25
39	100	23.98	36.632	24.90
40	125	21.89	36.739	25.60
41	150	21.09	36.710	25.85
42	200	18.30	36.433	26.30
		Station 8		
43	10	25.09	36.105	24.14
44	25	24.93	36.118	24.21
45	75	24.59	36.301	24.53
46	100	22.33	36.207	25.18
47	125	20.34	36.209	25.58
48	150	18.26	36.425	26.29
49	200	15.60	36.050	26.65
		Station 9		
50	10	24.70	36.125	24.28
51	25	23.64	36.090	24.70
52	75	20.40	36.147	25.62
53	100	18.51	36.098	26.00
54	125	12.12	35.528	26.70
55	150	11.80	35.480	27.04
56	200	--	--	--

Organic Carbon Parameters

Sample Number	Depth (m)	Dissolved (mg/L)	Particulate (mg/L)	Total (mg/L)
		Station 2		
1	10	0.90	.02	.92
2	25	0.49	.02	.51
3	75	0.66	.02	.68
4	100	0.76	.02	.78
5	125	0.52	.01	.53
6	150	--	.01	--
7	200	0.39	.00	.39
		Station 3		
8	10	0.45	.02	0.47
9	25	--	.02	--
10	75	0.44	.01	0.45
11	100	0.38	.01	0.39
12	125	0.39	.00	0.39
13	150	0.33	.00	0.33
14	200	--	.00	--
		Station 4		
15	10	0.42	.03	0.45
16	25	0.74	.03	0.77
17	75	0.46	.03	0.49
18	100	--	.03	--
19	125	0.45	.02	0.47
20	150	--	.02	--
21	200	0.27	.02	0.29
		Station 5		
22	10	0.28	.03	0.31
23	25	0.32	.03	0.35
24	75	0.58	.03	0.61
25	100	0.45	.03	0.48
26	125	0.48	.03	0.51
27	150	0.42	.02	0.44
28	200	0.34	.02	0.36

Organic Carbon Parameters (cont'd)

Sample Number	Depth (m)	Dissolved (mg/L)	Particulate (mg/L)	Total (mg/L)
		Station 6		
29	10	0.64	.02	0.66
30	25	0.52	.02	0.54
31	75	0.46	.02	0.50
32	100	0.52	.02	0.54
33	125	0.55	.01	0.56
34	150	0.36	.01	0.37
35	200	0.41	.01	0.42
		Station 7		
36	10	0.56	.04	0.60
37	25	0.51	.03	0.54
38	75	0.39	.01	0.40
39	100	0.37	.01	0.38
40	125	0.53	.01	0.54
41	150	0.30	.01	0.31
42	200	0.40	.01	0.41
		Station 8		
43	10	--	--	--
44	25	--	--	--
45	75	--	--	--
46	100	--	--	--
47	125	--	--	--
48	150	--	--	--
49	200	--	--	--
		Station 9		
50	10	--	--	--
51	25	0.63	.04	0.67
52	75	0.55	.02	0.57
53	100	0.69	.01	0.70
54	125	--	--	--
55	150	0.47	.00	0.47
56	200	--	--	--

Optical Parameters

Sample Number	Depth (m)	Parameter Transmission (%)	Attenuation Coefficient (m^{-1})
		Station 2	
1	10	88.22	0.501
2	25	88.19	0.503
3	75	88.17	0.503
4	100	88.20	0.502
5	125	88.85	0.473
6	150	88.99	0.467
7	200	89.30	0.452
		Station 3	
8	10	88.10	0.507
9	25	88.02	0.510
10	75	87.70	0.524
11	100	88.54	0.487
12	125	88.72	0.479
13	150	89.16	0.459
14	200	89.29	0.453
		Station 4	
15	10	88.42	0.492
16	25	88.36	0.495
17	75	88.42	0.492
18	100	88.35	0.495
19	125	88.71	0.479
20	150	89.03	0.465
21	200	89.14	0.460
		Station 5	
22	10	88.12	0.506
23	25	88.18	0.503
24	75	88.34	0.496
25	100	88.15	0.505
26	125	88.32	0.497
27	150	89.02	0.465
28	200	89.20	0.458

Optical Parameters (cont'd)

Sample Number	Depth (m)	Parameter Transmission (%)	Attenuation Coefficient (m^{-1})
		Station 6	
29	10	88.17	0.503
30	25	87.62	0.528
31	75	87.82	0.520
32	100	88.13	0.506
33	125	88.50	0.489
34	150	88.68	0.481
35	200	89.20	0.457
		Station 7	
36	10	87.97	0.513
37	25	87.93	0.514
38	75	88.10	0.507
39	100	89.08	0.462
40	125	89.32	0.451
41	150	89.36	0.450
42	200	89.36	0.450
		Station 8	
43	10	88.25	0.500
44	25	88.42	0.492
45	75	88.24	0.501
46	100	88.40	0.493
47	125	88.36	0.495
48	150	89.30	0.453
49	200	89.33	0.451
		Station 9	
50	10	--	--
51	25	87.31	0.544
52	75	87.35	0.541
53	100	88.27	0.500
54	125	--	--
55	150	88.95	0.469
56	200	--	--

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hydrography	particle sizes	organic carbon

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report is a summary and analysis of data collected during the spring of 1983 in Exuma Sound, Bahamas, and in the Gulf Stream at the Straits of Florida. Vertical profiles in the upper water column were obtained to characterize biological and chemical parameters, which might covary with propeller cavitation susceptibility.

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Examination of this data set reveals that Exuma Sound is a relatively homogenous body of water, with respect to the biological and chemical measurements that were made. It is an aquatic "desert," and any measurements made there of a parameter that may be influenced by biological or chemical activity cannot necessarily be extrapolated to other marine environments. This is especially true in regards to the more fertile regions, which exist in higher latitudes and coastal zones.